INSTITUTE FOR NATIONAL STRATEGIC STUDIES

Energy and National Security in the 21st Century

Edited by
Patrick L. Clawson

Energy and National Security in the 21st Century

Energy and National Security in the 21st Century

Edited by
Patrick L. Clawson

National Defense University Press
Washington, DC

National Defense University Press Publications

To increase general knowledge and inform discussion, the Institute for National Strategic Studies, through its publication arm the NDU Press, publishes *Strategic Forums*; McNair Papers; proceedings of University- and Institute-sponsored symposia; books relating to U.S. national security, especially to issues of joint, combined, or coalition warfare, peacekeeping operations, and national strategy; and a variety of other works designed to circulate contemporary comment and offer alternatives to current policy. The Press occasionally publishes out-of-print defense classics, historical works, and other especially timely or distinguished writing on national security.

NDU Press publications are sold by the U.S. Government Printing Office. For ordering information, call (202) 512-1800 or write to the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Library of Congress Cataloging-in-Publication Data

Energy and national security in the 21st century / Patrick Clawson, editor.
P. cm.
Includes bibliographical references.
1. Petroleum industry and trade—Government policy—United States—Congresses. 2. Energy policy—United States—Congresses. 3. National Security—United States—Congresses. 4. Petroleum industry and trade—Political aspects—Congresses. 5. Energy industries—Environmental aspects—Congresses. 6. World politics—1989—Congresses. 7. Twenty-first century—Forecasts—Congresses. I. Clawson, Patrick, 1951- .
HD9566.E53 1995
333.79'0973—dc20 95-40121
CIP

First Printing, October 1995

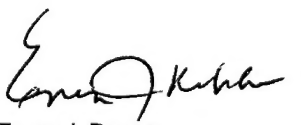
Contents

Foreword

Energy security was a major national issue during the 1970s and 1980s. In recent years, it received less attention as the price of oil declined and as U.S. oil supplies seemed more secure. But as we plan for the next decade, we have no reason to be smug. Many experts predict that the nation is likely to become *more* dependent on oil imports, and that the world will increasingly rely on oil produced from the politically volatile Persian Gulf. Given current trends, some contend that the United States and the world may be headed back toward oil price shocks like those in 1973 and 1979. Others disagree, arguing that the industrialized states will no longer have to worry about dependence on Persian Gulf oil.

This volume poses two central questions: (1) What does energy security mean now that energy supply is determined more and more by market forces? (2) What are the most likely circumstances under which the United States may have to apply diplomatic and military pressure to ensure orderly world energy markets? The papers collected here examine areas of the energy market of central concern for national security. They also consider energy prospects in key countries from the point of view of security, either because the countries are in volatile regions like the Persian Gulf or because they are major military as well as energy powers like Russia.

These analyses represent an exciting exchange of views among people from two rather different communities: those concerned with national security and those concerned with energy and economics. Now is a good moment, while our energy supply situation is comfortable, to reflect on whether the current, rather benign situation will persist and what preparations we should make against the possibility of energy supply problems.



ERVIN J. ROKKE
Lieutenant General, U.S. Air Force
President, National Defense University

Energy and National Security in the 21st Century

Introduction

Patrick L. Clawson

THE INSTITUTE FOR NATIONAL STRATEGIC STUDIES AND THE Department of Energy presented a conference in November 1994 on Energy and National Security in the Twenty-First Century. The key issues were:

- What does energy security mean now that energy supply is largely determined by market forces?
- What effects, if any, do other forces—geopolitical, environmental, technological and regulatory—have on energy security?
- What are the most likely circumstances under which the U.S. may have to apply diplomatic and military pressure to ensure orderly world energy markets?

In preparation for this conference, the Department of Energy commissioned a White Paper to be prepared by Pacific Northwest Laboratory and circulated to the invited speakers in advance of the conference. The paper, which discusses these issues and provides crisis scenarios, is included as the Annex.

Twelve distinguished speakers from government, industry, and academia addressed 100 participants on the essential question, "Is energy security a meaningful concept?" Conferees offered a qualified "yes" based on the profound changes that have washed the international scene in recent years. Conferees concluded that the end of the Cold War, the increasing sophistication and dominance of market forces, environmental concerns, rapidly rising demand for

---

Patrick Clawson is a Senior Fellow at the Institute for National Strategic Studies. A past editor of *Orbis*, Dr. Clawson was a senior economist at the World Bank and the International Monetary Fund.

energy in the Third World, and other events have significantly altered the energy security debate as the century winds to a close.

The collapse of the Soviet Union in 1991 eliminated the Russian threat to world energy supplies and opened the door for Moscow to become a key supplier of oil to the West. The rich energy resources of the former Soviet Union have attracted international interest and are providing a strong boost to the development of market economies in the region. This change in itself necessitates a fundamental rethinking of the concept of energy security.

Market forces have reduced the need for government involvement in energy markets worldwide but have not eliminated government's role in the energy security debate. Producers and consumers are ever more tightly linked in a global symbiotic relationship that significantly reduces the prospects of serious disruptions to energy markets. In this emerging reality the government role is increasingly indirect, supporting further evolution of market forces rather than direct intervention in markets.

Part of this reality is the tremendous need for capital—especially in the Pacific Rim, Russia, and Eastern Europe—to develop known reserves of oil and natural gas. Environmental concerns exacerbate these needs. One of the keynote speakers indicated that the interaction between energy and the environment would condition energy policy for the next 25 years—but the developed world considers the environment more an issue than does the developing world.

Rapidly rising energy demand in the Third World will test market mechanisms in the future and give rising importance to environmental issues. China in particular is poised to become a major consumer of imported energy resources. Unbridled economic expansion outside of developed economies points to possible adverse environmental consequences of accelerated energy use. Coordinated diplomatic initiatives almost certainly will be necessary to resolve such problems that will have progressively international implications.

The same market forces the U.S. Government is encouraging will leave the United States and the world economy more dependent on Persian Gulf oil, the cheapest source of energy available. The concentration of energy production in this one area leaves the world economy vulnerable to supply disruptions

born of political intrigue in the region which is being washed by growing social, demographic and economic troubles. The need for a continued military component to energy security is made manifest by this concentration of resources and social ferment.

Thus, rather than becoming less significant, energy issues will continue to be central features of the national security debate. The government remains responsible for insuring the free flow of energy resources at reasonable prices because the consequences of a major supply disruption are large and certain. Failure to address these new elements of the energy security debate will have serious consequences for U.S. and international economic and political harmony.

Is "Energy Security" A Meaningful Concept?

Phil Sharp, long-time chairman of the House Energy Subcommittee, vigorously argued that the best energy security policy is to have lots of people producing and lots of people distributing the energy that the U.S. needs—that is, minimize the risk from a disruption at any one point in the production and distribution chain. In this context, he said that the one enduring energy security question that requires diplomacy, military presence, and the willingness to use force is the concentration of oil reserves, production, and surge capacity in the Middle East.

He argued that the central imperative of energy security is having a vigorous domestic and international energy market. The virtue of this vigorous market was in evidence during the 1990-91 Gulf crisis. The surge capacity of the noninvolved states was sufficient to rapidly offset the disruptions in the market, allowing for a quick return to lower oil prices after an initial upsurge in prices. With such vigorous markets in place, we are likely to grow more dependent on imported oil, not less. And we are unwilling to pay the high costs of not being reliant on foreign oil. He suggest it might be "wiser to learn to love imports."

Backing up Mr. Sharp, former Amoco vice-president John Lyman argued that U.S. energy security is best maintained by ensuring that the United States is, and is perceived to be, fully supportive of free trade and of the use of market forces on a global scale. He agreed that we were unlikely to accept the large costs to avoid dependent on foreign oil. But, he noted, price spikes such as occurred during the Gulf crisis encourage

Congressional inquiry: "It is sometimes easier to talk about free markets than it is a to see them in operation."

Vito Stagliano of Resources for the Future argued that energy security is an empty concept used to perpetuate bad, self-serving public policy. He recounted the history of dramatizing energy issues and using energy as a reason for dubious public policy, in which category he included expenditures in excess of $100 billion between 1973 and 1992. The most important contribution to U.S. energy security during that period came not from any of the projects financed by this spending but instead by the de facto death of OPEC. That death, he argued, came from the 1981 U.S. Government decision to withdraw from oil markets, which spurted the growth of spot and futures markets that disrupted the ability of any government, including those of the OPEC countries, to control oil prices. John Riggs, Principal Deputy Assistant Secretary for Policy of the Department of Energy, replied that while the 1973 and 1980 oil shocks led to some inflated rhetoric and while energy security has been used as a justification for some pork-barrel projects, the fact is that the oil shocks did inflict significant economic harm on the United States. True, much (although certainly not all) of this harm arose because of the imposition of price controls, but that should not be used to minimize the effect that the oil shocks had on the economy and therefore the potential effects that a future shock could have. Mr. Riggs also argued that dependence on energy imports can reduce U.S. foreign policy options. As an example, he asked if the United States would have opted to bomb Libya in 1986 had world oil markets been tight? He suggested that the United States might not have taken such a strong stance against Libyan sponsorship of terrorism had it been concerned it could provoke another oil price shock.

Supply Disruptions

The participants agreed that the world oil supply system has changed since the oil crises of the 1970s and 1980s. The system now has much greater flexibility, thanks to a much larger role for market forces. On the other hand, Mr. Riggs cautioned against exaggerating the role of market forces. Since Saudi Arabia can produce oil at $2 to $3 per barrel and the world price is $17 to $18, something other than market forces seems to be at work.

After noting that regulations and price controls that encumbered oil markets in the past have now been largely eliminated, Hill Huntington of Stanford University's Energy Modelling Forum asked,how well and how quickly will markets work to adjust to a supply shock, and if they do not work quickly enough, will politicians step in with price controls or other such measures? He argued that macroeconomic models show that a doubling of oil prices would cut U.S. GDP by about 5 percent after a period of 18 months. He argued that in the face of such a considerable price, the U.S. Government was likely to adopt offsetting policies.

There was general support for the idea of buffer stocks to dampen the impact of a sudden supply disruption. However, others pointed out that now that energy is allocated more by market mechanisms, a supply disruption was likely to be felt as a price spike, and there would always be a strong lobby that argued that such a price spike was the market's way of forcing the economy to adjust to a supply disruption. In other words, the devotees of the free market would oppose use of a buffer stock in the event of a supply disruption, as seen in the wake of the Iraqi invasion of Kuwait when there was strong opposition to use of the Strategic Petroleum Reserve (SPR).

That led some speakers to argue that the SPR may not be worth the investment because it is unlikely to be actually used, while others argued that the SPR should be used to dampen price spikes. Whatever the arguments for or against the SPR, Mr. Sharp warned that the firm political reality was that Congress was unwilling to approve, and the voters were unwilling to support any increase in taxation on energy no matter how minor to fund the SPR.

When the discussion turned to the question of what might cause a supply disruption sufficiently large to disturb the U.S. economy, the general sense was that the disruption would have to be very large indeed (one speaker spoke about 3 million barrels per day for many months) and that the only realistic scenario is political turmoil in the Persian Gulf.

Tightness of World Oil Markets

The participants differed considerably in their evaluation of whether world oil markets are likely to become more taught or to remain slack, with ample unused production capacity. Guy

Caruso, the director for nonmember countries of the International Energy Agency (i.e., OPEC), reviewed the IEA's forecast that world oil demand will grow each year by about one million barrels per day in the 1990s, accelerating to almost two million barrels per day each year in the late 2000s, despite environmental policies and technological improvements that will shift the fuel mix away from oil. The IEA forecasts that the increased oil demand will be met overwhelmingly by OPEC oil, as production in the industrial nations declines. At the same time, international trade in energy will diversify as more natural gas and electricity are exported.

The major issue about energy demand considered at the conference was how rapidly oil demand will increase in the fast-growing East Asian economies. Milton Russell argued that Chinese energy demand will rise sharply, but that most of that demand will be met by domestically produced coal, with some role for hydro and nuclear power. He presented evidence for his thesis that China was going to remain dependent on coal, which in 1992 provided 74 percent of China's primary energy production. The increasing energy demand will be primarily for electricity, easily produced by coal, and for transport, for which China is heavily reliant on coal-fired or electric railroads (which indeed make good sense under Chinese conditions). He summed up by saying that China will remain a bit player on international energy markets. Indeed, he is much more concerned about the environmental impact of the massive greenhouse gas emissions China will be producing.

Fereidoun Fesharaki, director of the resources program at the East-West Center, took a different tack toward East Asia's energy future. He explained that the region's energy demand is rising quickly thanks to economic growth and that oil is a particularly cheap way to satisfy that demand. That means rising oil energy imports, especially from the Middle East. Today, about 36 percent of the region's oil comes from the Persian Gulf; in 2000, about 60 percent will, and this will produce a significantly altered landscape in terms of trade relationships.

With regard to U.S. energy demand, Gary Moore of the Department of Energy's Office for Conservation and Renewables argued that energy efficiency is an often underemphasized part of the energy equation. Much of the apparent gain in U.S. energy efficiency since 1973 has come from a shift away from

manufacturing and especially energy-intensive industry, which suggests there is ample room for future gains.

Turning to oil supply conditions, Vladimir Likhachev, deputy director of the Russian Academy of Sciences Energy Research Institute, argued that Russia is not likely to return to its 1990 oil output until 2010, with production continuing to fall until at least 1997 if not 2000.

On the other hand, Eliyahu Kanovksy argued that the difficult economic circumstances in which Saudi Arabia finds itself will lead that country to seek to increase its oil output as much as it can, in light of market conditions. But the same economic difficulties that create the strong need for revenue could also contribute to political turmoil that could, in an extreme case, lead to supply disruptions.

Nuclear Power as a National Security Issue

Robert Eynon of the Department of Energy's Energy Information Administration presented a detailed analysis of why nuclear power will be part of the U.S. and world energy mix for the foreseeable future. In the United States, much of the growth in electricity demand through 2000 will be met without building new baseload plants—for example, from renovating existing plants and from nonutility power producers—and even after 2000, the bulk of the new plants built will be fired by hydrocarbons, with natural gas increasing its share and coal remaining the main fuel. So the nuclear share in electricity output will decline from its present 20 percent, but it will not disappear. Worldwide, the aggressive nuclear programs in Asia and France will offset retirement of nuclear plants elsewhere in Western Europe, with global nuclear power capacity forecast to grow by 2010 by about 10 gigawatts from the present 330 gigawatts.

Thomas Cochran of the Natural Resources Defense Council discussed the proliferation concerns that nuclear power presents. The unanimous opinion of the arms control and weapons design communities is that the main constraint on a country's ability to produce nuclear weapons is the availability of fissile material, that is, plutonium or highly enriched uranium. Plutonium is a byproduct of nuclear power production. Four countries—the United Kingdom, France, Russia, and Japan—have heavy commitments to recycling and reprocessing plutonium from nuclear power

reactors, to reuse as reactor fuel. Unfortunately, even a small amount of plutonium from a civilian reactor is sufficient to make a nuclear weapon. The existing international control regime over nuclear material is not adequate to monitor plutonium flows, much less to prevent diversion of weapons use. Mr. Cochran argued for an international agreement to forego production, separation, and isotropic enrichment of weapons-usable nuclear material.

Implications for the U.S. Military

Most of the issues about energy security concern economic policy. Economists, by their professional orientation, prefer to use markets to provide a regular supply at an economically appropriate price. The increasing reliance on market forces for oil has served U.S. interests well by undermining OPEC's ability to keep oil prices high. Given the established track record of success that comes from relying on the markets, the U.S. Government is likely to use markets as the foundation of U.S. energy security policy.

But in the event of a large supply disruption, markets will not work quickly enough and well enough to satisfy the U.S. public. Economists may argue that buffer funds are the best insurance against large disruptions, but the experience of the last decade is that the U.S. public is not prepared to pay higher gas taxes to fund buffer stocks. On the other hand, there is a broad consensus that the U.S. must maintain a military readiness to defend its oil supplies if needed.

The need for a military component to energy security is made more manifest by the concentration of oil resources in the politically volatile Persian Gulf. The market forces the U.S. Government is encouraging will make the United States and the world economy more dependent on Persian Gulf oil, which is the cheapest source of energy available. That concentration of energy production in one area makes the world economy more vulnerable to supply disruptions, such as a dictator eager to create a temporary shortage that drives up prices or encourages others to turn a blind eye to aggressive plans.

I. Do Energy Imports Matter?

The Political View

Phil Sharp

THE FIRST QUESTION TO BE ADDRESSED by this panel was, "What does energy security mean, now that energy supply is determined more and more by market forces?"

The answer is simple: We have cheaper energy, we have greater supply, and we therefore have more energy security than if we had relied upon central control decisions to allocate energy resources.

Coming from the liberal end of the political spectrum and having been involved in a number of market interventions, I want to reaffirm at the outset my belief that the central imperative of energy security is having a vigorous domestic and international marketplace in which prices and allocation are determined by market forces rather than government diktat. When we use the market, we stretch our resources to be more efficient; we are more productive when searching for energy; we reward those producers and distributors who are most efficient, and who demonstrate skill at entrepreneurship; and we reward inventions

---

Mr. Sharp is Director, Institute of Politics, Kennedy School of Government, Harvard University. As a former Congressman, Mr. Sharp chaired the Subcommittee on Energy and Power of the House Energy and Commerce Committee and its predecessor subcommittee. He was the principal House sponsor and manager of the comprehensive Energy Policy Act of 1992, the leader in House passage of the 1990 Clean Air Act, and key sponsor of the successful Natural Gas Wellhead Control Act in 1989.

that keep energy cheaper and give us new technologies, such as horizontal drilling of natural gas, and natural-gas-fired combined cycle plants. When we have an open market, it is more difficult for anyone to monopolize or control that market; even OPEC came to that conclusion as their power waned. This is not to say that there are not problems, but overwhelmingly our central interest is in an international and domestic competitive marketplace for energy.

Central planning has a number of defects that have now become clear to us. Some of us had to learn this personally and others reached this understanding years ago, but it is quite clear that many of the problems in Russia and the former Soviet states arose from significant errors of planning, not least in trying to keep prices abnormally low. When we tried price controls and distribution controls in this country in the 1970s, we only compounded maldistribution of resources and ended up rewarding the import of oil.

I do not believe in a *laissez-faire* philosophy in which the government is given no room to intervene. We still have some natural monopoly situations like electric transmission and gas pipeline rates, although we are now finding ways to bring about competition in both of these areas. Governments have a role to play in well spacing in Oklahoma, Texas, and other places. We also want the government to help set up an active futures trading market and to prevent price fixing. There are a number of areas in which government has a role to play; most notably, the marketplace tends not to adequately recognize environmental costs, and therefore governments must find various ways to impose these costs on the system. Although it is not my intention to address that issue here, I will mention that I believe most energy policy over the next 25 years will involve the relationship between the environment and energy.

There is also a role for government in cases where we see significant market failures. There are times when military interventions or political turmoil, particularly in the Middle East, will have a dramatic effect on the world oil market that can hurt us all. For that reason, we and our International Energy Agency (IEA) colleagues have taken measures to stock oil supplies. We have the Strategic Petroleum Reserve (SPR) of about 590 million barrels, which we can inject into the market at a rate of up to about 2.5 million barrels per day. The total IEA (including the United States)

can put out something like 3 million barrels per day, so it is possible for us to have an impact on that marketplace. About the same quantity of surge capacity exists, we believe, in the oil-producing countries. If we are lucky, as we were in the Persian Gulf War, and have an alignment of interests in which those with surge production capacity are on the same side as those with significant strategic reserves, this can have a major stabilizing effect upon the marketplace.

Over the past 20 years, we have constantly seen the conventional wisdom on energy issues overthrown. This reinforces the importance of allowing markets to function. Markets are not brilliant, but they figure things out better than we are able to, because our assumptions are so often wrong. For example, according to the conventional wisdom of the previous 15 years, the Persian Gulf War should have been disastrous from an oil and economic perspective. But we had reserves, we had surge capacity available, and Saudi Arabia was lined up with the United States, Western Europe, and Japan. Admittedly, this was a set of fortunate circumstances that may not repeat itself. On the other side of the coin, if one of the major producers in the Middle East, especially Saudi Arabia, were to be unexpectedly knocked out temporarily or worse, for a long term, then we could face a deep supply disruption with profound consequences for Western markets.

But the fact is, we are unwilling to pay the significant price that would be necessary to be insulated from such contingencies. Since we started out with Project Independence under President Nixon, we've had endless speeches that rail against energy imports, but in many ways, to borrow a line from Stanley Kubrick's *Dr. Strangelove,* we have learned to stop worrying and love these imports. Many of us wish at some level that we were not so dependent on imports, and we talk about how we would be more secure if we could reduce our dependency on imported oil by, say, two million barrels a day. But a quick test of where we really stand on this issue is to ask ourselves whether we would have been willing to go to war against Iraq if our oil imports had been four million barrels per day, instead of seven or eight million. I think the answer is that it would not have made a difference, because we were concerned about other kinds of political and strategic interests as well. Of course, oil was very significant, but this was less because of concerns that Iraq would control the international oil

market than because we were worried that Saddam Hussein would use enormously enhanced oil revenues to build up his military and intimidate others in the Persian Gulf. It is a myth that we went to war in the Persian Gulf simply because of oil.

Recently, a colleague insisted that we needed to have an energy policy in this country to avoid being put in the position where we would have to sacrifice the men and women of this country for the sake of oil. Yet neither he nor anyone else I know will vote for an energy policy that would make us independent, because that would probably mean paying something like $80 per barrel for oil in the U.S. economy, in order to drive down domestic demand and bring new domestic sources on line. Admittedly, no one can give a precise figure, but if we drive up the price of oil enough, we can certainly be independent of foreign oil. Of course, then we would have to worry about issues like how our firms could compete internationally and which ones we would wreck in the process—and nobody is willing to do that.

The truth is, we do not want to be so regulated in our use of energy or pay massive subsidies or high prices that would substantially isolate us from the world economy. It simply does not make sense to strive for energy independence at such a cost. This is not to argue against marginal efforts, but the question of cost effectiveness remains central in any reasonable discussion of energy security. There is big disconnect in this country between the speeches that we make and what we are in fact willing to do.

I suggest that it is in fact wiser to learn to love the imports— or, to put it less provocatively, to recognize that we are part of the international community and the international economy. To some extent, we must worry about certain places like Saudi Arabia, but to assume that we can obtain security by striving for energy independence is pure nonsense. We are better served to argue about specific policies for addressing how we would manage a crisis, how we would employ diplomacy and the military in such a situation, and when we ought to use the SPR.

I personally believe it is important for us to continue to expand the SPR. But even there it is difficult to argue that our scarce resources are better spent on the SPR than on some of the other pressing demands in our society. Although there is bipartisan support in energy circles both inside and outside the government for maintaining the SPR, support for putting dollars into it up front has been waning for quite some time. Bennett Johnson and I both

tried various approaches to paying for the SPR in our committees; we essentially decided to put it on the backs of the oil companies, who would in turn put it on the backs of the consumers, at the rate of about one-half cent per gallon of gasoline. One-half cent per gallon, however, was more than the political system would bear, and we lost massively in the vote. We tried to be very candid with the public, assuming that a half-cent tax per gallon of gas would be acceptable, but the public remains quite sensitive to any type of tax hike. Consequently, there was no stomach in the Congress to take this very modest and, I believe, useful step.

I do not want to disparage the importance of planning for contingencies or focusing on potential trouble spots in the world oil or natural gas markets, but we must not fall into the trap of thinking that we can set policy on the assumption that we will know how much oil we will use in 5 or 10 years, and where it will come from. Change occurs so fast that no one is able to say with much confidence what that picture will be. Such projections can be useful as an intellectual exercise, and sometimes they will lead to good policy consequences, but the most important lesson is to resist screwing around with markets unless you have a good reasons, because they will undoubtedly allocate resources better than we can. The "solution" to our energy security anxieties is therefore to have lots of people producing and lots of people distributing the energy resources that we need.

The second question put to this panel was, "What are the most likely circumstances under which the United States may apply diplomatic or military pressure in order to ensure orderly world oil markets?" Let me first of all challenge that phrase "orderly world markets." Markets are not orderly. They do, however, help solve the normal human chaos problem of how large numbers of people can live together and pursue their own ends, and they do it unbelievably and mysteriously well. World oil prices go up and down—that's just the nature of the beast—and in general, we have to be willing to let this happen. However, one exception that I would make is that we should be prepared to use the SPR if, for example, we lose Saudi Arabian production, or if the Saudis decide it is not in their interest to use surge capacity at some key moment.

The one enduring energy security question that clearly requires diplomacy, military presence, and the willingness to use force under some circumstances is the concentration of oil reserves,

production, and surge capacity in the Middle East. Even if we could somehow reduce our imports of oil from that region to zero, that would not reduce our interest in the region's stability, because a price shock in world oil markets would have many indirect effects on world markets from which we cannot hope to insulate ourselves.

Another energy security issue is unrelated to supply questions. The collapse of the Soviet Union brought a reduction in the financial status and prestige of the skilled personnel who built and oversaw Soviet nuclear capabilities. These personnel now have an interest, unfortunately, in selling their skills and the goods of their trade. Whether they are honorable or not, there are enormous incentives for them to disperse throughout the world, including to places that are not interested in neighboring nations' well being. The risk is not just that such personnel might help to set up the expensive infrastructure for a national nuclear weapons program; it is also that such personnel might be paid to apply their expertise to the manufacture of other instruments of terror, such as chemical bombs or devices to release radioactive materials in population centers. This is not an issue addressed directly by U.S. energy policy at the moment.

While energy security remains an important consideration, future interventions in the marketplace are more likely to be for environmental reasons. There will also be instances when equity considerations will push our political system to intervene. For those who believe that the recent political re-alignment in the Congress reduces or eliminates the threat of market interventions in the energy sector, I would point out that in 1970, some of the strongest free marketers in the U.S. House of Representatives voted for price controls, owing to political pressure. Richard Nixon was in the White House when price controls were imposed unilaterally by his secretary of energy, that great oilman John Connally. Sometimes this history is forgotten. Some people argue that we have gotten beyond that, but I submit that memory will be very weak both inside and outside the government when the talk shows once again start to discuss energy dependence, Exxon's profits, Saddam Hussein, or whatever, and the political pressures start to mount. When another energy crisis looms, skilled political management will be very important, so that we don't intervene in the wrong way and make matters worse.

The Industry View

John P. Lyman

I FIND THIS SUBJECT DIFFICULT to address succinctly, as it involves an extremely complex set of dynamic forces. The industry has always fascinated me, as politics, economics, technology, and now environmental concerns all play critical roles. Today I will provide the perspective of someone who has worked for 30 years on the international scene and for 28 in the oil and gas business.

I was specifically asked to discuss if energy imports really matter to the United States. My first observation is simple. Growing imports are a reality. The question is, can and should they be avoided or minimized to increase U.S. security? I would suggest that this cannot be done without prohibitive cost over the next 10 to 15 years. Some believe we can avoid dependence on overseas supplies by reducing demand and or subsidizing alternative energy sources. While such developments would slow down the growth in oil demand, they are unlikely to reduce our dependence upon imports significantly, unless the U.S. public is willing to pay exorbitant penalties vis-a-vis the world economy.

At the same time, I do believe we should encourage alternative fuels, new technology and more efficient uses of energy. The debate centers on at what cost. It is one thing to sponsor a new idea over a startup period, and another to provide subsidies that either directly or through tax incentives ultimately lead to uneconomic production. Even in the United States this is becoming more important as limited resources need to be spent on other needs such as health, housing, and dealing with poverty.

John P. Lyman recently joined Mercer Management Consulting as Vice President in the Oil and Gas Group. Mr. Lyman spent the previous 28 years in the Amoco Corporation in a number of progressively more challenging assignments. He is a member of the American Petroleum Institute and is active in the Atlantic Council, as a member of the Steering Committee on U.S. Energy Policy (1991-92) and on Russian/Ukrainian Energy Policy.

In this world, U.S. energy security is best maintained by ensuring that the United States is, and is perceived to be, fully supportive of free trade and the use of market forces on a global scale. The United States taking this position with both energy suppliers and other consuming nations will be our best assurance of being able to weather any storms. U.S. energy security needs to be thought about as a global security issue, not solely as a U.S. issue.

My comfort in this solution is based on a fundamental belief that the equalization of factors of production on a global scale is an irreversible, long-term process. Protectionism, denial of market access, and retaliatory trade practices may slow the process, but eventually they will cause large enough economic distortions to cause a country to change its policies. These changes can be dramatic as in Russia, or more gradual as in the U.S.A., Japan, and China.

It is obvious that countries proceed at significantly different paces in their attempt to economically develop and improve living standards. What is sometimes forgotten is that industries, such as petroleum, also speak with many voices. Hence, although the oil majors will tend to encourage free-trade policies, U.S. independent producers will simultaneously seek financial support for U.S. production. Even among the integrated oil majors, there are wide differences of strategy and position such that it is difficult to find a unified industry position on most major substantive issues.

Another basic issue for this conference is, what is an energy crisis? In the 1980s, short-term cutoffs have been fairly easily handled by letting market forces work. This has proven far more effective than allocation schemes or price controls. When price spikes occurred they have quickly returned to normal as supply realigned. Fairly large dislocations were handled in this manner and even the price pain associated with the Iraq War was relatively easily absorbed. The biggest problem has been shifting transportation routes and preventing shortages at particular locations owing to logistic restraints. Although the economy adjusts relatively easily to short periods of higher prices, the price spikes frequently become the subject of congressional inquiries. Let's just say,it sometimes is easier to talk about free markets than it is to see them in operation.

Most of us are aware that the supply/demand balance for oil as well as most other energy sources, including electricity, have tightened considerably. While I agree with this analysis and will

discuss it further, the question for us today is, will this lead to more severe crises? I would hypothesize that while more frequent mini events may occur because of pipeline closures etc., the global market place is resilient and will continue to operate effectively. The key will be in treating supply disruptions as world events and allowing worldwide realignments to occur. This will spread the impact and minimize the potential effect on any one consumer of a particular source of supply. In this regard, it is very difficult for a given supply point to concentrate its actions on a single consumer or group of consumers, if global markets remain open and unrestricted.

This is probably the right point to ask, do we really need a Strategic Petroleum Reserve? If we do, then its size and capability to deliver quickly are critical. If one believes most supply disruptions will be of short duration, how likely is it that the SPR will be used? Experience to date suggests that administrative reaction times are slow,and there is an unwillingness to use the SPR to stabilize prices. If this is true, then one could hypothesize that it is unlikely to be used except in extreme and extended circumstances. In this case, the SPR is helpful but not much of a long-term solution owing to its size relative to demand. Moreover, the delivery mechanisms are slow and poorly tested, leading many to believe that finding alternative supplies is a far more economic and practical solution. This is especially true in the longer term event covering 2 to 4 years during which new production can be brought on stream and demand patterns can be changed.

At this time, many in the petroleum industry view the strategic petroleum reserve as an expensive investment in inventory with high carry costs and little potential for a return. In short, it is thought to be a noneconomic investment unlikely to be effectively utilized.

A related issue for the conference is "the circumstances under which the United States would be most likely to use military or domestic pressures on energy matters." The answer depends both on the administration in power and the events themselves. Nevertheless, I suspect the answer is that military power will be used only in very rare events like the Iraq War. Even in this case, if it had been clear that Saddam would have stopped at Kuwait, it might have been a different response. Thus, industry in general does not believe that they must rely on gun-boat diplomacy to solve disruptions to pipelines, shutdowns because of civil

disruptions, or governmental nationalizations. Most have learned that working with governments as partners is more profitable than treating our foreign hosts as adversaries. Moreover, in the event of turmoil, adversarial relationships take longer to get back on track than those which were initially based on mutual respect. This understanding is crucial in the energy business as most projects take 5 to 7 years to build and 15 to 20 to pay off.

On the other hand, government's diplomatic efforts to encourage free trade, reduce obstructions to markets, and open investment opportunities have and should continue to be useful levers. This is most effective when U.S. interests are clearly understood by both sides. In this regard most myths have already been refuted, including:

- The United States can win any war.
- The United States can solve any problem it sets out to tackle.
- The United States has the resources to help everyone.

The final area I will address today is the likely nature of energy supply/demand relationships over the next 10 to 20 years. Speculation in this area is usually misleading. The one thing I have learned is that economic forecasts are seldom accurate. However, we have also learned that it is not the forecast that is critical. Rather it is an organization's ability to react. If we know the key factors impacting events, organizations can usually adjust and survive most changes. It is the unexpected and unmonitored events that are most likely to destroy one's company.

I do not intend to provide yet another forecast; rather I will discuss the major forces that need to be watched, namely political, economic, technology, and environmental concerns. Almost all major decisions in the energy area are impacted these areas, which are also the key to supply/demand relationships. The strengths of these forces vary widely by constituency both at the national and company level. This divergence of position is just as critical to understand as are the long-term trends, because it can lead to very different answers for individual nations and companies especially over the short and intermediate term. Hence, one always needs to step back and look at these forces when discussing events in individual countries.

Firstly, critical political pressures usually prevail over the other forces in the short term, although they are themselves shaped by economic, technology, and environmental concerns. Thus,

political considerations may override sound decisions from the other three perspectives. For example, Hussein will not step down to improve the well being of the Iraqis, and communism in the 1950s and 1960s clearly was not supportive of economic or environmentally sound solutions for development. Technology is not equally applied throughout the world, sometimes because governments don't want the social change implicit.

I may be biased, but economics is the most enduring concern and usually dominates over time,. Although frequently ignored in the short term, it becomes socially too painful to ignore over the longer term. Thus, the oil industry, as well as other energy industries that are dependent upon very long-term investment, concentrates on solutions that are economically sound. They have to if they are to stay in business. Governments might be wise to follow a similar rule if they want to be remembered kindly in history. Despite myths to the contrary, the integrated petroleum business has a tough time earning its cost of capital. For a number of years there has been unrelenting pressure to lower costs, and major technological developments in the use of computers and drilling have led to a significant downward shift in the cost of production. However. there have been few if any major breakthroughs that would radically alter the industry's production costs. It is generally believed that the petroleum industry will continue to experience gradual rather than jolting technological impacts. Also, the opportunities for cost reduction are likely to be less dramatic in the coming decade.

New products, from competing energy sources such as electric cars and compressed natural gas vehicles will gradually erode the demand for petroleum transportation fuels, but the major impact will go beyond the year 2000 and probably beyond 2010. Relentless pressure to improve economic performance along with a reduction in cash flow due to the low-price environment, has caused most surplus capacity to disappear in all energy industries. As a result, the world currently faces tremendous capital requirements, especially in the Pacific Rim, Russia, and Eastern Europe. Environmental concerns add to these capital needs. In this regard it is worth noting that the United States has a propensity to seek more expensive solutions and higher standards than would appear reasonable to others, especially the developing world. Taken together, the economic, technology, and environmental forces would be expected to lead to a

gradual rise in prices to cover capital cost increases associated with new investments. However this does not mean that overall industry rates of return will rise. It will be important for policy makers not to mistake higher earnings for windfall profits .

Oil will not be cheap, but it should be reasonable, especially relative to other products, as world markets mature and labor rates equalize over time. It is critical to world economic development that capital is allocated into the energy industry if future energy supplies are to materialize. If supplies are forthcoming, and global economic development is encouraged by free trade and the world adoption of market economics, energy security will be assured for all. I suspect that addressing those developments will be the ultimate challenge for governments too often sidetracked by short-term political pressures.

Discussion: Energy Imports

Question: How will China's shift from a net energy exporter to a net energy importer affect the petroleum industry?

John Lyman: China in this past year has become a net energy importer, and most analysts assume that this shortfall will continue to grow. The question is, at what pace will the Chinese government allow the growth in demand for transportation fuel to occur? I think they will encourage it, and we can foresee a couple of million barrels a day in increased demand for imported oil. I believe that the world can supply this added demand. Most of the growth in world demand will be in Asia—not just in China, but in India, South Asia, and the Pacific Rim. But at the same time, the U.S., and Europe will have fairly stagnant growth rates. So overall, a maximum 2 to 3 percent growth in world energy demand is expected. That will be manageable if we do the things that need to be done, like helping to put the Russian oil industry back on its feet and China to develop its coal technology and resources. If nothing else happened, China's increased demand could be a problem; but other things will happen, and it is important to get capital out there to support these developments.

Question: Please comment on the competition between oil and natural gas, particularly in regards to the environmental dimension.

John Lyman: The problem with liquified natural gas (LNG) is that it is incredibly expensive and very difficult to transport. Having said that, I believe there will be increasing use of LNG, but users will have to be prepared to pay a substantial premium for it. LNG will probably experience increased use in Japan, which is willing to pay such a premium because it lacks other indigenous sources of transport fuel. The United States has always been a market that is reluctant to pay premiums. Further, we in the United States have always been able to find ways to sell petroleum transport fuels of ever-increasing quality at reasonable prices. It will be difficult for natural gas, the use of which will involve the creation of a huge new infrastructure, to take over large segments of the U.S. transport fuel market. However, there are particular segments of the market where LNG will be appropriate and can be economically applied—in trains, big diesel trucks, or fleet vehicles

in cities. Eventually, LNG might take up to 10 percent of the demand for that type of fuel, but we don't see it totally taking over. It will come, but very slowly; it is certainly no panacea for oil imports.

Question: Considering the low savings rates and government deficits in the U.S. and most other industrialized countries, where is the capital for new energy investments going to come from?

John Lyman: The U.S. taxpayers, via the U.S. government, cannot and should not support these capital requirements throughout the world. Governments, particularly in China, Russia, and India, must change their policies to allow investments to naturally take place in those countries. Both the Russian and Chinese governments are well aware of this. The problem is how to go about doing it when the energy industries represent such an important source of tax revenues. When they milk these industries for tax revenues, it stifles investment. The Russians in particular have been paying attention to this, but it will take a while; I would expect a pretty rocky road for the next 5 to 10 years. I am always impressed by the resiliency over time of people's willingness to invest. What I don't know is whether, where the supply of capital seems to be tight, this is because capital is unwilling to move in, or because people have gotten smarter in their use of capital and only put it in when it is really needed. I do know that we must be careful not to confuse higher prices with exorbitant rents -- to assume that, because an industry is earning substantially more money now than it was a year or two ago, its profits are now "too high." Without such profits to compensate for risks, the necessary investment in energy will not take place.

Question: Please give more specifics about the role of government in energy security.

Phil Sharp: I would put heavy emphasis on being prepared to manage an extreme situation, both politically and substantively—particularly in regard to opening up the SPR. Using the SPR is a very difficult issue, because it is a matter of judgment when such use is justified. My personal prescription for enhancing energy security would be to fill the SPR further, but I think that this is out of the question at this time because of economic, political, and

budgetary realities. In fact, I believe that the real focus through the medium term will be on diplomatic and military initiatives in the Middle East. On a related point, the alternative vehicles program was presented as an energy security matter—as a way of reducing dependence on foreign oil. I must admit to some uncertainty in my own mind about how far we should go in trying to reshape that market. Certainly, the program should not be driven in any significant way, or funded to any large extent, on the assumption that it will buy us energy security, because other market factors change so fast. Suppose it did help reduce oil imports for light vehicle transportation needs, what would happen? If it truly had an enormous impact on demand for oil, oil prices would drop and industrial users might consider increased use of oil—it's a cycle you cannot beat by design. But from an environmental standpoint, we do have to work out how we are going to have clean air and clean water with high levels of energy production and distribution. From that standpoint, alternative vehicles may be important. I also believe there is a role for the government in long-term research and in ensuring that the private sector gets access to what we are doing in government and university labs.

John Lyman: Congressman Sharp and I agree on most points, but we disagree on the value of the SPR. I don't disagree that it is a deterrent and a hedge, particularly in the case of disruptions in the supply of Saudi Arabian oil. But for losses of less than a million barrels a day, we'll never use it; we didn't even use it during the Persian Gulf War. Considering our extreme reluctance to actually use the SPR, the substantial costs of filling and maintaining it may, over the long run, offset any benefits we might derive from it. One positive sign I see is the growing recognition that you can't examine energy issues in isolation—trying to solve oil problems while ignoring natural gas markets or the environment, for example. We are learning to think more holistically. This creates complexity and administrative problems, but when you start to think this way, you start to see the issues differently. The prime question that policy makers should address is what is the right level of support for energy programs and the acceptable level of environmental costs, given the other needs in the U.S. and world economies.

Phil Sharp: I would like to add a word about politics here. Currently, we have moratoria on offshore drilling that cover most of the continental shelf of the East and West coasts. I personally think there should have been more of an effort to negotiate and find those areas that should be closed off, while allowing drilling in other areas. Since I am a Democrat, and Democrats have a tendency to be more interventionist on environmental issues, some might see a contradiction here—but recall that it was George Bush who instituted the moratoria on California and Florida. Of course, he did it for very strong political reasons; he was under pressure to maintain his popularity in these states, and offshore drilling had become a very intense local issue. I bring this up not to criticize him, but to make the point to watch out for making political assumptions that people who share your general ideology or philosophy about the marketplace will perform as you expect them to, because in the political world, one does not always get to make the choices that one might like. It takes a lot of political effort to get many of these energy issues resolved, and you can't assume that an issue will be resolved to your satisfaction just because of you have a President or a member of Congress who happens to share your views, because it takes a lot of groundwork for such officials to be able to do what they want to do.

Question: Please comment on the likely effects of U.S. attempts to live up to targets of framework convention on climate change?

Phil Sharp: Personally, I believe the most likely outcome is that we will not live up to the targets. There will be administrative steps taken and efforts in the private sector, but if the more pessimistic estimates about the effect of this shift on energy use and prices are anywhere near being correct—and admittedly, the estimates are all over the lot—there is no political will to get there. Of course, this may change in 2 or 3 years, but by then we are almost to the deadline. The other question is, will we be leading or following the Europeans? The Europeans took a more aggressive position when the treaty was being put together, but I'm not sure that they are following through to live up to the goals that they set for themselves. I personally believe that it is acceptable to proceed cautiously in this matter, owing to the great uncertainty that currently prevails concerning the causes, effects, and extent of global climate change. At this point, we should be pro-active,

but not at high cost. The best strategy for now would be to take all of the low-cost steps, or those steps that have other economic or environmental value to us, until we learn more about the problem and what we can do about it. Others, of course, would disagree; some believe climate change is the most profound issue of our time.

John Lyman: All I would want to add is that climate change is not an issue that can be resolved by the U.S. and Europe alone. It is a world issue; and when the global nature of the problem is mentioned, everyone starts zeroing in on Russia and China again. The important question here is whether these two economies can afford the costs associated with addressing the climate change issue. I think the answer is clearly that they can't. So it is incumbent upon Europe and the U.S. to find cheap ways of transferring the technology to such countries that will lessen these costs. So we can also address global warming by figuring out what we can do to take the technology that we in the industrialized nations have today—and that we know is significantly better than that being applied elsewhere—and introduce it in other places cheaply. One of the things the Europeans did to modernize their plants after World War II was to give faster tax writeoffs for new investments. This strikes me as a reasonable and politically acceptable approach; it is not taking dollars from the pockets of U.S. taxpayers if you tell investors that they will be allowed a faster write-off for investments in new technologies that will benefit the environment. That will get capital moving into that sector faster. And once the write-off is over, you have the plant there—making money and building the economy.

Phil Sharp: I agree with that, but I would add that the Europeans had a political advantage after World War II in that they didn't have to worry about what to do with all the old stuff; that had all been taken out during the war. On the other hand, in this or almost any other country today, the old is always arguing against the new, and saying, "Why do they get the tax credit? Why don't we get the tax credit?" We seem to be going through a fundamental process of re-examination. Today, we have to ask, to what degree do our governments—any of our governments—have influence over their own economies? They can clearly do

things to screw them up; that is very clear. But we have become so dramatically integrated in the world economy that government management of national economies is exceedingly difficult to exercise. Of course, I believe that nations will be around for a while. We sometimes talk as if economics was the most important consideration for nations, but economics is usually less important than what is in people's hearts. When people in their hearts say, "We are French Canadians," or "We are Serbians," the economics often go out the window.

Question: Can you suggest some specific situations in the Middle East that could cause disruptions in energy supply and threaten energy security?

Phil Sharp: Clearly, Saudi Arabia is the main issue. Why would one presume that Saudi Arabia will be different from everywhere else around the world, and will stay politically stable in this tumultuous era? In a rapidly modernizing world, why would one make that assumption over the long haul? True, they've done a remarkable job of doing maintaining stability, but why bet one's fortune on the proposition that Saudi Arabia will not experience internal problems that could disrupt oil production? Why assume that the royal family, which is very large, very diverse, and has its own internal conflicts, will not splinter into feuding factions, and perhaps splinter the country with it? What if the influence of religious extremists causes the Saudis to be become less conciliatory? The last time we needed Saudi Arabian surge capacity, the Saudis were on our side. What if the problems next time happen to be in Venezuela, Iraq, and Indonesia, so what we have several smaller crises adding up to a disruption in world oil supply, and we need Saudi Arabia's one and a half million barrel surge capacity, and the Saudis say, "No, this isn't a problem—we can't get politically involved in this"? One just never knows; the permutations of what could go wrong are just endless.

Question: By maintaining low oil prices, the U.S. increases its dependence on foreign oil. Is an import tariff on oil, on top of any consumption tax, out of the question for this country?

Phil Sharp: This is a political, not an economic question. The inability to pass the very modest BTU energy tax in 1993 illustrates

the political difficulty here. My sense is, this issue will continue to resurrect itself in various ways. The gasoline tax itself was not, to my knowledge, an issue in any race in the recent elections—although "tax and spend" certainly was. However, that was probably because the price of gas is still so low. In fact, I think the last two times we raised the gasoline tax by a nickel, the price actually fell—but we were extraordinarily lucky, politically speaking, in how that came out. I personally believe Congress is oversensitive to the political fallout from small increases in the gasoline tax. If you are ever going to sell any kind of consumption tax to the public, however, it won't be on the basis of energy security. I just don't think that issue sells, and I don't think you can entirely justify it, either. Perhaps promises of building roads, cleaning the environment, or providing other benefits will eventually induce the public to swallow some sort of oil tax, but I don't think the country is ready to accept a general consumption tax for the sake of energy security.

John Lyman: I would personally prefer to see a consumption tax, rather than an import tax, because an import tax raises anti-free trade questions. I would rather deal with the whole issue, as have the Europeans and the Japanese, on the consumption side directly, rather than through the back door of an import duty, which gets you into trade wars and everything
else.

Phil Sharp: One other policy that has been toyed with was a floor on the price of oil, through an import fee type of arrangement, which would encourage investment in exploration and drilling in the United States. However, once you start talking about a guaranteed floor, someone inevitably asks the question, "Yes, well how about when the price goes up at the other end; are we going to set a price ceiling as well to protect the consumer?" Usually, the political system won't allow you to deal with just one side of the equation in this manner.

Question: What are the economic and security implications of a sudden loss of access to Saudi oil?

John Lyman: We're talking about perhaps 6 to 8 percent of world supply. It would be dramatic, and prices would go up. But we

have ask, what has the world done before when the oil markets took hits of that order? Have we made appropriate adjustments in demand? The answer is yes. Of course, we would see wild price swings, but could the people in this room consume, say, 10 percent less gasoline? Would you feel your life was devastated, or could you handle that for 6 months? If the effects of such a disruption were spread out fairly evenly, the world would probably adjust to it. So even with disruptions of that magnitude, you can find ways to handle it, even if you would rather not have to. If we get Russian production back, that will be a better safety valve by orders of magnitude than worrying about what happens in Saudi Arabia tomorrow. So if you want to have a national energy security policy, why not use a few billion dollars to help the Russians get their oil production back? That's probably the most effective security measure you could take. It diversifies your suppliers, and it is a lot cheaper than going to war. We've been lucky for the past fifteen years in Saudi Arabia, but who knows when that luck runs out? If we started to assist Russia right now, it would take years to show major results, but you could probably reverse the decline in production pretty quickly. In terms of restoring production levels to where they were in the 1980s, I have seen a lot of estimates that in five to ten years you could really make a difference.

Phil Sharp: I agree that one of our foremost interests is in helping to get our former enemy back on its feet economically. As a market force, as a supplier of energy, as a potential source of instability on Europe's doorstep, Russia remains a paramount interest. If you could get the Russian government to settle the question of property rights, so that people could make reliable contracts, I think you would be surprised how rapidly some production could be restored in the event of a crisis in Saudi Arabia. It still would take months. But look at Kuwait. Most of the estimates were dead wrong about how long Kuwait's production would be out and how long it would take to extinguish the oil well fires. Why? Because it was in somebody's imperative economic interest to get the job done. I believe that John is correct that economically we would adjust to a cutoff of Saudi oil, and that the market would take care of it. What I have worries about is that, since it is so difficult for any of us to understand exactly what is happening in the international markets, the politics are absolutely right for conspiracy theories—and foreign governments,

the oil companies, the labor unions, the military, or whomever will get blamed for it. When the public begins to believe that *somebody did this to us,* you get all sorts of political gyrations that can be very difficult to deal with. And the greatest likelihood is that we will overreact in some way. That's why I favor the SPR; at least the government has some way of saying "there is something we can do, and we are doing it" and act, look strong, and maybe even have an impact. Presidents always feel that they have to look like they are leading us out of the swamp, even if they know that it is not that simple. Part of that leadership is bringing people to understand that this is a real crisis; when this is understood, it is amazing how much cooperation you can get. The problem is that every talk show host in this country, not to mention most politicians on Capitol Hill, will be saying "we *would* cooperate, but we know who is responsible for this, and we should go after the villain." And then you run into very profound political questions about how to keep the public behind you without doing anything precipitous.

II. Key Energy Countries

Russia's Potential as an Energy Producer and Exporter

Vladimir Likhachev

I WILL DISCUSS THREE MAJOR POINTS TODAY: The present situation of the Russian energy sector, Russian energy strategy for the future. and Russia's energy export potential.

Russia is not only an important energy producer, but is also a large consumer of energy resources. The former Soviet Union was the second-largest energy consumer in the world after the United States, and Russia consumed 62 percent of the Soviet Union's domestic energy resources in 1990.

In 1990, per capita energy consumption was 8.3 tons of coal equivalent (t.c.e.), compared with American consumption of 11.6 t.c.e. per capita. Energy consumption in Russia was characterized by very low consumption of oil, particularly light oil, because of the undeveloped transportation system and low number of passenger vehicles per capita. At the same time, the energy intensity of GDP, according to the estimates of international organizations, as about 20 percent higher than in European countries. We had, and have, a huge potential for gains through energy efficiency, perhaps about 500 million t.c.e., or 40 percent of current energy consumption. The main areas for improvements in energy

---

Dr. Likhachev is Deputy Director and Head of the Laboratory for Energy Balances at the Energy Research Institute of the Russian Academy of Sciences. In 1994-95, he was a Visiting Scholar at Oak Ridge National Laboratory and at the Resources for the Future in Washington, DC.

efficiency are in the energy complex itself—in electric power generation and the gas and oil industries—and, of course, in our residential and industrial sectors.

During the last 3 years, with the start of economic reform, Russia has witnessed a decline of about 10 percent in electricity consumption, and a similar decline in the consumption of primary energy resources. Over the same time period, official statistics indicate that GDP dropped by about 30 percent, which suggests that the energy intensity of GDP rose about 1.4 times. These official statistics, however, do not take account of the underground economy, which may produce up to 20 percent of Russian GDP.

Russia has a huge potential for energy production. Estimates of the World Energy Council indicate that Russia has about 30 percent of world reserves of natural gas, 30 percent of coal reserves, and about 20 percent of oil reserves. Unfortunately, many of these resources are located in the northern reaches of the country, and are very difficult and very expensive to exploit. During the last 3 years, Russia lost 35 percent of its crude oil production; this has been the most significant event in the Russian energy sector. Also, declines in coal production began in the mid-1980s and continue to this day. Natural gas production, however, continues to more or less meet the energy demands of the Russian people and economy.

The energy complex of Russia began to experience problems in 1988, when our oil production began to drop. But now, during economic restructuring and reform, the main reason for such problems is the crisis of investment and finance. Above all, this is a result of nonpayment for energy supplies and of the social protection policies of the Russian government—for example, trying to keep unemployment at an abnormally low level and failing to enforce bankruptcy laws. Another reason is that the government has practically stopped investing in the energy sector, and the main source of investment is now private resources. The energy sector likewise has been handicapped by a lack of foreign investment and by a very inefficient voucher privatization program that gives every person in Russia a claim on state property, but contributes nothing in terms of real investment. The investment environment in Russia today is characterized by a lack of stability in laws governing the energy sector, an unstable tax regime, a

shaky state financial system, the decline of solvency in the domestic market and other CIS countries, a loss of access to traditional foreign energy markets, and insufficient investment by the state in basic infrastructure construction.

To improve the situation with energy production, the Russian government proposed an energy strategy based on encouraging competition through price reform and privatization; upgrading institutions; introducing new legislation; establishing a new relationship between the federal and local governments; and attracting foreign investment. The Russian Government and Ministry of Fuel and Energy are now stressing pricing policy—specifically, market pricing for all nonmonopolized energy resources such as oil, oil products, coal, and steam coal. For energy sectors in which competition is limited (electricity, central heat production, and gas), prices will be set at the federal and regional level, and the government will try to keep control of the basic financial conditions in the electricity and heat production sectors. Because of the huge distances between regions of energy production and regions of energy consumption, it is also necessary to keep in mind the need for upgrading infrastructure, such as railroads and pipelines.

In the past 3 years, the ruble price for crude oil increased by 1,000 times. Of course, this figure does not in itself say very much, because Russia had monthly inflation of about 300 percent in 1992, and only during 1994 has this been reduced to 8 to 10 percent per month. However, in terms of dollars, prices in Russia for oil products in the middle of 1994 were practically at the same level as world prices. We still have insufficient prices for oil, but this is mainly because Russia has a very underdeveloped refinery sector, and the output of light oil fuel from Russian refineries is still only 60 percent, compared with more than 80 to 90 percent in Western countries.

Russia's energy strategy between now and 2010 will stress improvement of energy efficiency, and consequently environmental protection. We also hope that it will be possible to maintain the growth of natural gas production and to stem the reduction of oil production. Further, it will be necessary to address the situation in coal production, which is in full collapse at the moment; because of price liberalization in coal and lingering price controls on natural gas, there are practically no customers within

Russia for Russian coal. Further, huge transport distances have resulted in logistical difficulties and very high prices.

Through the year 2010, policy to improve the efficiency of energy use in Russia will proceed in three stages. First, and most cheaply, changes in management are expected to save 20 million t.c.e. The second stage involves the introduction of new technologies, mainly from Western countries. And the third step is the reorganization of the Russian economy. To evaluate these energy efficiency policies, the Russian Government considered two scenarios, one optimistic and the other realistic. In the more optimistic estimations, our levels of energy consumption will not regain 1990 levels until 2010, and use of primary energy sources will never again reach 1990 levels.

At the same time, we will also have large difficulties maintaining energy production levels and will not reach the 1990 level of production until 2010. In terms of oil production, pessimistic estimates foresee a substantial decrease until the year 2000; other scenarios suggest that between 1997 and 1998, we may begin to see stabilization in production. However, production of natural gas will increase in the near future. Because of technological, safety, and psychological reasons, Russia will devote only limited attention to nuclear energy.

Other important issues include the European energy charter, the special relationship between Russia and the other former Soviet republics, and relations between Russia and other foreign countries. The main markets for Russian energy exports are the European market for gas, in which Russia will compete with European producers and new suppliers from Africa and the Middle East, and the far eastern (Pacific) market. By optimistic measures, Russia can provide the Pacific market with 20 billion cubic meters of natural gas both by pipelines and via LNG.

Finally, Russia's energy exports by 2010 may approximately double from their current level, and these will mainly consist of natural gas shipments to Europe. Unfortunately, we do not have the technical and transportation capabilities to export more than 100 tons of crude oil by 2010.

Energy Prospects in China

Milton Russell

THE CONCLUSION OF THIS PAPER is that China is not likely to have a substantial direct effect on U.S. national security through its presence in world energy markets for the foreseeable future, defined here as roughly the next two decades. However, the size of the Chinese economy, its dominating political and military presence in Asia, and the opportunities it presents for energy-related investment and for development of energy technologies, including renewables and nuclear power, make the potential indirect effects of its energy production, conversion, and use worthy of serious attention. This conclusion rests on six energy propositions:

- China will be expanding its use of all forms of energy at a rapid rate over the next two decades.
- The Chinese economy will remain coal-dominated despite the increase in use planned for liquid fuel, hydro power, and natural gas.
- This expansion will create a market for very large-scale imports of foreign technology and capital--perhaps the largest and most concentrated energy-related investment market the world has ever seen.
- Transformations underway will change China from a net liquid fuels exporter to an importer, but the magnitudes will not by themselves be such as to destabilize international oil markets.
- Chinese economic development will be accompanied by sharply rising emissions of greenhouse gases. It will also be accompanied by a major expansion in the market for pollution control equipment, much of which must be imported.

Milton Russell is Director of the Joint Institute for Energy and Environment (JIEE), a collaborative partnership between the University of Tennessee, Knoxville (UTK), Oak Ridge National Laboratory (ORNL), and the Tennessee Valley Authority (TVA). He is also a Professor of Economics at UTK and a Collaborating Scientist at ORNL. (Mr. Ling Yun, UT, provided valuable assistance in the preparation of this paper.)

- These trends appear to be robust, barring catastrophic internal instability. Further, they will be affected only in degree by the success or lack of it in fostering greater energy conservation or use of renewable energy technologies.

The size and complexity of the Chinese economy and its energy sector make any effort to deal exhaustively with these themes impossible in the space presented here. The goal instead is to provide the salient facts that might be most useful to those who need to factor China into their energy-related national security thinking and planning.

While the focus here is on the Chinese energy system and its potential impacts on U.S. national security, this topic is deeply embedded in overall developments in China.[1] Therefore, the place to begin is to gain some sense of the Chinese economy and its potential role in the world. To do this, it is necessary to examine key factors in future production trends. It is well known that China has about 1.2 billion people, over one-fifth of the world's population, and that despite substantial success in limiting births, this number will rise to about 1.7 billion before beginning to stabilize in the middle decades of the next century.[2] Because the Mao policy of encouraging births was superimposed upon the normal population increases found in countries with rising life expectancies, this is a young population now entering the peak of its productive years. Underemployed labor exists in massive quantities, found in the ubiquitous overmanning of industrial facilities and in the vast rural sector, which still contains some 900 million people on overmanned farms and in often-inefficient local industries. For a developing country, this is a young, relatively literate, potentially productive labor force. Moreover, it is one eager to earn the ticket to consume the goods that are regularly paraded on almost universally available TV.

Unfortunately, 40 years of rigid planning and the "iron rice bowl" did not equip China with the labor discipline and the managerial depth required for full success in a large, complex, market-driven economy. This is changing and can be expected to change even more rapidly in the future. Thus, the shortages of skilled labor now cropping up should dissipate with continuation of existing trends, which are facilitating labor mobility and greater managerial control of the work place. Managerial talents remain in scarce supply, because needs are growing so rapidly and many potential recruits to middle-management positions found small

entrepreneurship so attractive financially as the economy was first loosened from the rigid grip of bureaucratic controls. Here, too, conditions will change as the reforms deepen. While training of new workers is required and productivity remains low, labor supply should pose no constraint on continued expansion for the foreseeable future.

Transportation is and will be a constraint. Transport is rail dominated and grossly overextended in moving both people and goods, especially coal which absorbs about 40 percent of the rail capacity.[3] Rail expansions are underway and will absorb large amounts of capital over the next two decades, even while the more visible expansion of the highway system gets most of the publicity.[4] Coal-by-wire schemes are expected to relieve some of the stresses, but rail expansion is at the heart of China's transport future.

The third factor that will dictate China's future success is its agriculture. Food supplies and prices are undoubtedly the first thoughts on arising and last thoughts on retiring of China's leaders worried about social stability. Agriculture was the first sector freed from Maoist controls and responded with rapid increases in output which have now tapered off to more modest gains (table 1). For the country as a whole, food supplies remain adequate and are supporting a steadily improving diet with more animal protein and more vegetables for much of the population. This disguises regional pockets of poverty—pockets, but nonetheless ones of a size that leave perhaps 100 million people sometimes without enough crude calories to support full activity.[5] The challenge of China's leaders is to provide the agriculture sector with the capital, technology, and incentives that will allow steadily increasing output in the face of continuing deterioration of the soil and loss of highly productive land to urban development. The race can clearly be won in the near term with appropriate policies; the long-term sustainability of Chinese food and fiber self-sufficiency is more problematic.[6]

The fourth factor is infrastructure, including communication. Building a modern industrial economy on top of a poor agrarian society involves not only factories but the housing, public services, and communication facilities required. Visitors to China over the past decade can attest that the overwhelming impression is of a large construction site. The task is far from over, and the gaps in services as basic as water, waste disposal, and public

transportation are enormous. It appears, however, that not only has China's infrastructure kept up with other economic growth, but that the balance is actually improving. Comparisons are difficult, but impressions are that China's infrastructure has not suffered the relative deprivation apparent in most other similarly situated developing countries. Still, infrastructure will continue to absorb a disproportionate share of available capital for some time to come if China is to continue to see improved living conditions.

This brings us to the fifth factor, capital availability, the true limiting factor for China's future development. The government has succeeded in mobilizing citizens' savings at a prodigious rate, partly through the expedient of inflation. Foreign investment has been growing and will need to rise exponentially if China's ambitious plans are to be realized. Problems will come if the romance of investment in China fades before the reality of policies that do not allow secure, profitable operation. Strains are now appearing, as investment shifts from small-scale, export-oriented, quick-return ventures in the coastal provinces to long-term, large-scale activities for the Chinese market, such as power plants and coal mines.[7]

The last factor in China's future is reform of overall economic policy, including financial policy, and its concomitant, maintaining social stability. China embarked in 1978 on a path of reform that would transform decisionmaking by plan to decision-making by decentralized markets under a loose planning structure (table 2). This process has continued by fits and starts since. Much is made in the public press about the ideological tugs and pulls among economic "reformers" and "hard-liners," especially in this period of run-up to Deng Xiao Ping's death. The tension is real, and the stakes are high for the Chinese and the rest of the world. It is important, though, to realize that the battle is mostly being fought over the *pace* of change; there is no substantial body of thought supporting going backward. The freeing of the economy has unleashed productive forces and social changes that cannot be tamped back down. The crux of the issue is how fast change can occur without fostering so much pain on those left behind by progress—unemployed workers, de-powered officials and bureaucrats, the poor, and the distressed inland regions—as to threaten social stability. The reform tiger the government is riding can be ravenous, and the trip is fraught with peril. If the economic gains can be sustained and be spread more equally while a social

safety net is built to replace the "iron rice bowl," the process can continue. But a substantial recess from change can not be ruled out.

The most critical element in this reform is also the one that goes most against the grain of Chinese culture—the imposition of the rule of law to replace the personal exercise of power. One facet of this, of course, is the issue of "corruption." Favors given and received and the use of position for personal gain have been the norm in China for centuries. The rise of Mao did little to change the basic equation. Money, as well as power, came from the barrel of a gun. In prereform China, however, such practices were less visible and odious comparisons less easy to make. Now, the issue is manifest, and Chinese society is far more open. Further, a market-based economy demands predictability, sanctity of contract, security of property rights, and all the other attributes that transform the chaos of individual decisions into an effective mechanism to produce and distribute goods. Progress in achieving the rule of law (a high priority among reformers) will be a touchstone for continuation of the Chinese success.

Holding the energy situation aside, the conclusion from a review of basic factors in the Chinese economy is this: there is no inherent reason to believe the Chinese economy has "topped out" and that future growth will slow precipitously. Indeed, one could say that China is just now poised on the "take off" phase of development. All this could fall apart for a year or so in political and social unrest, but the fundamental bases for substantial continued growth exist.

And the record thus far is remarkable. The one overwhelming fact is that China is now roughly tied with Japan as the second largest economy in the world when measured on a purchasing power parity basis. Barring catastrophe, on the same basis China will surpass the United States in less than two decades. This is somewhat misleading in economic terms because so much of China's agriculture production, included here, does not go through markets. Still, China is in eleventh place as a trading nation and moving up. The message is clear: China is a major force on the world economic scene and will only grow larger as time passes. This was until recently not the case.

The Chinese GNP grew at a compound rate of 9.4 percent over the period 1980 to 1993, and by 13 percent in 1992 and 1993. Growth in 1994 was running at an 11 percent rate after 9 months

(table 3, compound rate calculated). The economy in real terms is about four times larger than it was when Mao died. This growth is all the more striking in that agriculture, which is still about one-third of the economy, was unable to sustain marked increases over the past 5 to 8 years. The growth has come in industry, construction, and services. The year-over-year increases in industrial output have been about 20 percent or more since 1992.[8] Again, looking to the future, there is no reason to believe rates of growth will fall markedly, though the double-digit levels of the recent past cannot be sustained. The major risks lie in a sudden restriction of investment in China to curb inflation, or in repressive measures taken during the political transition, but these interruptions are not likely to last long.[9] This suggests that it would be reasonable to project growth at a level that will double China's GNP by shortly after the turn of the century, and double it yet again in the subsequent decade.

With this background the discussion can now turn to energy and national security. The feedback of energy on economic growth in China needs to be mentioned before addressing the six propositions with which this paper started. In brief, lack of adequate energy supply has been a substantial drag upon the Chinese economy and will remain a troublesome issue for some time to come. This is not the place to discuss the pricing reform, which, over the past few years, has gone far to cushion the negative effect of the lack of prior investment in energy. Notwithstanding price reform, energy supplies are still to some extent allocated; for the most part markets, especially for electricity, do not clear. Energy shortages are commonplace in China. It is impossible to determine how much overall GNP growth has suffered from policies which did not allow reallocation of resources into energy and most productive uses of available energy, but the amount is probably significant.

With respect to future overall energy use, the drivers are economic growth, structural change, prospects for efficiency improvement, and previously unmet demand. Economic growth prospects were discussed above. Energy use has grown more slowly than output, but this is only partly because of structural changes and greater efficiency—a more powerful force may have been the rank shortages that constrained consumption. In the future, the emphasis will continue to be away from heavy industry, which means greater demand for higher quality energy

and less use of raw energy per unit of output. Policies such as higher prices are entrain to encourage greater energy use efficiency, but these will not be bearing conservation fruit for some time to come. In part, this is because major segments of the Chinese economy are not completely integrated into a market system so that prices can affect those who can respond effectively. For example, even as substantial funds are going into district heating schemes and improved boilers for space heating, the apartment buildings being constructed are innocent of even rudimentary insulation, and heat controls for individual apartments seem to consist of opening and closing windows. Further, in the capital-short situation in which China's industry finds itself, new facilities may take advantage of energy-saving technologies, but typically they add to, not replace, existing production lines.

Finally, there is the matter of unserved demand. As noted, energy shortages are ubiquitous. It is commonly thought that at any one time up to 20 percent of Chinese industry is inoperative because of lack of energy, mostly electricity.[10] Urban households are buying appliances, including air conditioners, at rapid rates only to be faced with rolling blackouts, which will almost certainly grow worse before they get better.[11] In addition, rural and interior China must start catching up to the improved living conditions of the East if social stability is to be maintained. This will mean a burgeoning demand for electricity and especially for liquid and gaseous fuels to replace the more noisome use of crop residues and other biomass on which most rural Chinese now depend for cooking and other domestic uses. Taking these factors together, it is reasonable to conclude that the recent period of energy growth trailing economic growth is an artifact of a special set of circumstances; effective demand for energy will equal or outpace economic growth for some time to come, constrained only by supply.

This leads to the second point. Where is this energy to come from? And the answer is the same as it has been for the past 40 years—rom coal (table 4). Leave aside the rural use of biomass, both in households and small industries, and concentrate on commercial fuels. Coal consumption is now on the order of 1.1 billion metric tons per year and reserves exist to sustain that level and much more for the foreseeable future. Projections are for consumption to reach 1.4 billion metric tons by 2000 and to continue growing.[12]

Coal dominates the Chinese economy in a way unseen in the West for a half century or more. Not only is it the primary source of fuel for electricity, but it also provides the bulk of industrial, commercial and household fuel as well, with some of the latter in the form of manufactured gas and briquettes. The coal mining industry is undercapitalized, largely antiquated, and labor intensive, but still vastly overmanned, and highly polluting and dangerous. Nonetheless, it has continued to expand, based on the massive reserves in North Central China and in widely dispersed small fields that provide fuel for local industries. Transport is the key bottleneck now, and rail shortages have bedeviled industry and electric generation throughout the country during the past 4 years of rapid expansion.

The dominance of coal does not mean that China has neglected other energy sources (table 5). Hydro potential is being exploited both with small dams and with projects such as the planned Yangtze Three Gorges project, which is expected to provide about 18 GW of capacity by the time it comes fully on stream in some 20 years.[13] Lan Cang River development in the southwest--known more familiarly as the Mekong--will exceed 12 GW capacity when completed.[14] Current hydro capacity is about 40 GW, and projections are for as much as 70 to 80 GW by the turn of the century.[15] But, again, even these massive projects take on a different perspective when placed against the size of current unmet electricity needs, much less those of the next two decades.

Petroleum is yet another story. The Chinese economy has relied upon the Daqing oil field in the northeast as its base, but this field is past maturity and output is in long-term decline. Other onshore reserves have been disappointing in the East, as have offshore efforts. Greater openness to foreign investment and technology over the past few years promise a rapid but measured expansion in output here. It is in the forbidding desert of Xinjiang Province in the far west that China's petroleum hopes must lie. By all accounts, the Tarim basin contains elephants—on a par with the near-greatest fields in the world—but getting the oil out and to market will be a daunting challenge. Not only is it difficult drilling in a hostile environment without local infrastructure, but the Tarim is 2,000 tough miles from the consuming centers of the coast. Production is beginning, but full utilization must be more than a decade away.[16]

Natural gas now supplies only about 2 percent of China's energy. Offshore reserves are being developed and expansion is being pushed, but unless surprises occur, gas will remain a specialty fuel. It likely will be dedicated largely to petrochemicals and to urban uses as a weapon against local pollution.

The Chinese are aggressively pursuing the nuclear option. Their first facility went online in 1994 and others are under construction. The policy is to ramp up nuclear with all deliberate speed to form a sound foundation for a substantial component of electricity supply several decades out. Earlier excessively optimistic projections were for 6 GW to be on line by 2000, with another 6GWs under construction. It is still hoped to have 15 GW in place by 2010.[17] China is developing an indigenous nuclear industry but is also in the market for reactors and other components from abroad. China could be the longed-for market that allows scale-up of a new generation of reactor designs.

A word about renewables. Rural China already depends on crop residues and wood for most of its fuel. Despite government efforts, consumption of wood is almost certainly greater than replacement. The trend is away from traditional renewables and toward commercial fuels as incomes rise. Expansion of the renewable share using modern renewable technologies must buck this trend. Success will be measured by the degree to which new technologies penetrate to make renewable use sustainable, and to offset the otherwise expanding use of commercial fuels.

Putting all this together, expansion in noncoal commercial energy will likely do little more than keep up with the overall growth in commercial energy use, at least for several decades. The energy mix in which coal dominates is not likely to change very much.

This picture of a growing energy industry leads to analysis of the third proposition listed above. China will be a magnet for foreign investment in energy technology and capital. The sheer magnitude of the investments required is awesome. For example, China is planning to build 135 GW of electric power plants by the year 2000, and more than 270 GW by 2010. Officially, China expects about 25 percent of the capital to come from abroad.[18] Thus far the flood of foreign firms seeking a part of this business has resulted in only a trickle of actual deals made. The Chinese are feeling their way along and have failed so far to put in place the kinds of practices and institutions that would achieve success.

The goals for foreign investment will almost certainly not be met. But even with the stretch-out anticipated, the magnitudes involved are unprecedented. In total China plans to put in place about one-half of all the new electric facilities in the world over the next decades. When the central station investment is added to the requirements for coal mines, power lines, and railroads, not to speak of distribution facilities, the task is mind boggling. There is clearly no way that China's industrial infrastructure can accomplish this task alone. Equipment of every kind will be required from abroad. The prime opportunities, of course, exist for technology licensing, specialty equipment, and advanced engineering services. But the market also exists for the basic equipment to be provided by manufacturers abroad—the turbines, mining equipment, switching gear, generators, and other components that China does produce, but not in sufficient quantities.[19]

What is true of electric power will also be true of the petroleum industry where advanced technology to bring the new oil and gas fields to market is less developed in China. In terms of its influence on world energy markets, these pressures on the energy investment side are likely to have far more significance than the impact of China on world oil markets, the usual way in which developments within nations affect others in the world. In brief, China must find markets for its goods that will bring in the hard currency necessary to pay for these investments and to maintain a rising standard of living. Its freedom to use costly economic weapons as a means to reward or punish others will be circumscribed as it becomes even more integrated in the world economy.

This leads to the fourth point, the impact of China on world oil markets. In the past, China sought to maximize its oil exports as a means of obtaining needed foreign exchange. Exports peaked in the mid-1980s at about 600,000 barrels/day and have been tending downward since that time. While production has roughly stabilized at just under 3 million barrels/day, consumption continued to rise until 1994 saw the crossover from net exporter to net importer. The next decade will see a race among increased production from new fields, declines in old fields, and rising consumption that can be expected to yield a period of import growth. Close observers differ on the prospective magnitudes. Estimates range around 1 million barrels/day by 2000.[20] For the

longer run, everything depends on the rate at which the Tarim Basin fields can be brought to market and offshore fields can be exploited. Still, the prospect is for China to become a significant oil importer (table 6).

In the light of all these factors, the direct impact of China on world energy markets is likely to be noticeable but not substantial over the next two decades. Because it is likely to remain roughly self-sufficient in both oil and coal, China, while a giant in other respects, will be a bit player when it comes to roiling international energy supply and demand balances. The story could change in the long run, of course, depending on its success in bringing new resources into the market. And its influence in other ways could be enormous.[21]

China's likely small influence on global energy markets is in stark contrast to its growing importance in global greenhouse gas emissions. The size of its economy, the inefficiency with which energy is used, and the dominant role of coal mean that China's energy sector alone will be ranked high in the list of net emitters of greenhouse gases. When other sources such as methane released from coal beds and from rice paddies are included, China's contribution soars. The expansion of coal and other fuel use described before suggests that over the next 30 years China will become the largest emitter of CO_2 in the world.[22] The only energy-related actions that would dampen this growth would be those which lessen fuel use, especially coal. This translates into measures to improve energy use efficiency and to move even more forcefully into alternatives with a lower greenhouse gas impact.

Efficiency is both a big target and one of urgency, especially because so much capital is being embedded both in long-lived facilities such as buildings and in new conversion facilities. A strategy with similar long-term payoffs would focus on providing high-quality renewable alternatives in rural China where commercial energy use is now at very low levels and the infrastructure has yet to be built. The Chinese are certainly aware of these opportunities, but the urgency of the economic development mission understandably puts these considerations lower on the agenda inside China than they would appear on the wish list of the international community. If the world wants China to go beyond its narrow, necessarily near-term, self-interest in these matters, strong efforts will be required.

Other aspects of environmental protection are of large and growing concern in China. Energy-based insults cover the range from the regional land and water impacts of coal-mining to the health-and amenity-estroying effects of fuel combustion. With regard to air pollution, many of China's cities are now holding their own with respect to particulates and SO_2, but automotive pollutants are growing worse almost everywhere. Regional acidification is also nting problem.[23] The mood is growing in China for a more expansive effort to improve environmental quality, but in this area, China clearly lacks productive capacity. Markets for technology, expertise, and equipment can confidently be expected to grow.

These, then, are the major factors that are most likely to affect the Chinese energy situation as it could relate to the national security of the United States. The size and importance of the Chinese society and economy in virtually any dimension are such that the United States must take it into account when formulating policies with respect to energy and national security. However, the direct national security concerns arising from China are likely to be small compared to those from other parts of the world.

This conclusion must be balanced with caution. China is in the midst of one of the most dramatic changes any major country has experienced. It is westernizing, modernizing, and industrializing at a great rate, even as it is growing perhaps faster than any major country in history. It is doing this while it is also changing power relationships, both among government units with a devolution of power to the cities and provinces and away from Beijing, and between the government and its citizens. There is substantial political discord in the provinces on the periphery, including oil-rich Xinjiang. There is a shifting from a rigidly controlled, egalitarian, planned society to one of apparent chaos dominated by markets. China is going from an "iron rice bowl" welfare state to one of free-labor markets where people are cast on their own resources. And it is doing all this at a time of political fragility because the "great man" model of leadership, the only one China has ever known, will be fractured at Deng Xiao Ping's death. In this cauldron of change, anything can happen.

But the reading here is that the processes underway are essentially irreversible. One should expect that there will be temporary upheavals of the sort that have occurred over the past 15 years. Further change and economic/political reform will

occasionally take a backseat to a pause or even retrogression in some dimensions, but the pattern has been set. A revolutionary cataclysm of the magnitude of the Cultural Revolution is possible, but unlikely. Given this view of China's future, those who are looking to the long term with respect to the connection between China's energy situation and national security can rely on the six themes struck here:

- Chinese energy use will rise dramatically.
- The Chinese economy will remain coal-dominated.
- There will be large opportunities for the export of energy-related technology, capital and equipment to China, and this will integrate China even more firmly into the world financial and trading system.
- China will not seriously roil international oil markets.
- Greenhouse gas emissions will rise sharply and environmental control markets will grow.
- These trends appear robust, barring unlikely catastrophic internal instability.

Notes

1. The author has no special credentials that allow him to speculate on possible Chinese foreign policy or related matters. Consequently, this paper does not consider these relevant topics.

2. Eduard Bos, My T. Wu and Ann Levin, "East Asia , South Asia and Pacific Region Population Projections," *Working Papers of the World Bank* (November 1992), WPS 1032.

3. International Energy Agency, "China," *World Energy Outlook*, Chapter 6 (1994 edition), 185.

4. "Transportation—Ambitious Plans to Extend Road and Rail Links," *Institutional Investor* (October 1993), 554-556.

5. Frida Johansen, "Poverty Reduction in East Asia," *World Bank Discussion Papers* (1993), 2.

6. Lester Brown, "Who Will Feed China," *World Watch* (September/October 1994), 10-19.

7. Henry Sender, "Pulling the Welcome Mat--Beijing Gets Tough on Foreign Investment in Power," *Far Eastern Economic Review* (April 14, 1994), 74-75; Patrick E. Tyler, "China's Power Needs Exceed Investor Tolerance," *The New York Times* (November 7, 1994).

8. "China and Mongolia," *EIU Country Report* (3rd quarter 1994), 7; Liu Weiling, "Year-end Growth on Right Track," *The China Daily* (November 14, 1994). While EIU forecasted a growth rate of 16 percent in 1994, the China State Information Center declared that industrial output during the period is expected to be $139.5 billion, up 22.6 percent over the same period last year (first 10 months of 1994).

9. See table 3 for the annual real growth rates between 1980 and 1993. What is most striking is that the years the Chinese label as economic failures, 1989 and 1990, nonetheless saw growth rates of over four percent. These were years when economic authorities were trying to restrict growth to hold back inflation. They were also the years when the Tianamen crisis most affected tourism and foreign investment.

10. David Schneider, Jessica Madoc-Jones, and Guo Liming, "Power Plays--Economic Implications of the Power Shortage in China," *The China Business Review* 20 (Nov-Dec, 1993), 20.

11. Jayant Sathage and Stephen Tyler, "Transitions in Household Energy Use in Urban China, India, the Philippines, Thailand, and Hong Kong," *Annual Review of Energy and the Environment* 16 (1991), 319-327; International Energy Agency, "China," *World Energy Outlook*, Chapter 6 (1994 edition), 178-179; Zhou Weirong, "Appliance Sales Gain Stability in Year-end," *China Daily* (November 7, 1994).

12. International Energy Agency, "China," *World Energy Outlook*, Chapter 6 (1994 edition), 192.

13. Ibid., 163.

14. "Power--New Emphasis on Private Participation," *Institutional Investor* (October, 1993), 5510-5512.

15. International Energy Agency, "China," *World Energy Outlook*, Chapter 6 (1994 edition), 163.

16. "China Stepping Up Foreign E&P Investment as Oil Imports Soar," *Oil & Gas Journal* (May 9, 1994), 56-58.

17. International Energy Agency, "China," *World Energy Outlook*, Chapter 6 (1994 edition), 168-169; Chanc Weimin, "US to Help China Clean-up its Coal," *China Daily* (August 1, 1994.

18. Peter C. Evans, "Building Ties with China," *Independent Energy* (March 1994), 42-27.

19. David Schneider, Jessica Madoc-Jones, and Guo Liming, "On Your Market . . . Foreign Companies Compete for Contracts in China's Power Projects," *The China Business Review* 20 (Nov-Dec, 1994), 34.

20. "China's New Oil Import Status Underpins World's Most Dynamic Petroleum Scene," *Oil & Gas Journal* (May 9, 1994), 33-35; New analysis by Fereidun Fesharaki and Associates at the East-West Center was reported at the Conference in which import levels of around 3 million barrels/day by 2000 were forecast. Fesharaki also reported that the Chinese were expected to place heavy demand on products for some of this supply. If Chinese imports indeed rise as far and as fast as the East-West Center analysts contemplate, pure market pressures exerted will be substantial.

21. The conclusion of no major oil market impact with implications for national security is subject to the important caveat that China will not seek special influence with oil exporters by force or other means but instead will depend on established markets for oil. While nothing can be ruled out, there is no evidence that China will follow any other course.

22. D. R. Simbeck, R. L. Dickenson, and L. D. Carter, "China's Coal Use," *Independent Energy* (July/August 1994), 80.

23. National Environmental Protection Agency of China, "1993 Report on the State of the Environment in China," (1994).

Table 1. Rural Reform and Agriculture Production

Year	Privatized (%)	Grain Production (million tons)	Oil Crops (thousand tons)	Cotton (thousand tons)
1977	0	283	4,017	2,049
1978	0	305	5,218	2,167
1979	1	333	6,435	2,207
1980	14	323	7,691	2,707
1981	45	325	10,205	2,968
1982	80	355	11,817	3,598
1983	98	387	10,550	4,637
1984	>99	407	11,910	6,258
1985	>99	379	15,784	4,147
1986	>99	392	14,738	3,540
1987	>99	403	15,278	4,245
1988	>99	394	13,203	4,149
1989	>99	408	12,952	3,788

Sources: Data on privatized percentages are from Justin Yifu Lin, Richard Burcroff II, and Gershon Feder, "Agricultural Reform in a Socialist Economy: The Experience of China," *The Agricultural Transitions in Central and Eastern Europe and the Former USSR*, A World Bank Symposium (Avishay Braverman and Karen M. Brooks, eds.). Data on grain, oil and cotton production are from the State Statistical Bureau of the People's Republic of China, *China Statistical Yearbook*, 1990.

Table 2. Share of Gross Value of Industrial Output by Form of Ownership

Year	State Ownership (%)	*Nonstate Ownership (%)
1978	77.6	22.4
1980	76.0	24.0
1985	64.9	35.1
1990	54.6	45.4
1993	52.9	47.1
1992	48.4	51.0

*Non-state ownership includes collectively owned, individually owned, and other ownership.

Source: Data for 1978 to 1989 are from the State Statistical Bureau of the People's Republic of China, *China Statistical Yearbook,* various years. The data for 1990 to 1992 are from Michael W. Bell, Hoe Fe Khor, and Kalpana Kochhan, International Monetary Fund, "China at the Threshold of a Market Economy," September 1993.

Table 3. Growth Rates of GNP, Primary Energy Production, and Electricity Generation

(annual percent change over previous years)

Year	Real GNP[1]	Primary Energy Production [2]	Electric Generation [3]
1980	7.9	-1.2	6.6
1981	4.4	-0.7	2.9
1982	8.8	5.6	5.9
1983	10.4	6.8	7.2
1984	14.7	9.3	7.3
1985	12.8	9.9	8.9
1986	8.1	3.0	9.5
1987	10.9	3.6	10.6
1988	11.3	4.9	9.6
1989	4.4	6.1	7.3
1990	4.1	2.3	6.3
1991	7.7	-1.2	9.0
1992	13.0	2.9	11.3
1993	13.4	N/A	8.2
1994	11.2	N/A	N/A

Sources: 1) Real GNP growth rates for years 1980-1992 are from "China at the Threshold of a Market Economy," *IMF*, 1993. Real GNP growth rates for 1993 are from *EIU Country Report*, 3rd quarter 1994, "China and Mongolia." Data for 1994 are from "Year-end Growth on Right Track," *The China Daily* (November 14, 1994) and should be considered preliminary. 2) Primary energy production growth rates for 1986 to 1990 are from *China Energy Databook*, various years. Primary energy production growth rates for 1990-1992 are from *EIU Country Report*, No. 1 1993, "China."3) Electric generation growth rates for 1980-1985 are from *China Energy Databook*, various years. Electric generation growth rates for 1986-1993 are from prospectus of Huaneng Power International, Inc., "The Electric Power Industry in the PRC."

Table 4. Shares of Primary Energy Production (percentages)

Year	Raw Coal	Crude Oil	Natural Gas	Hydroelec-tricity
1950	98.0	0.9	0.0	1.0
1960	96.0	2.5	0.5	1.0
1970	81.9	14.2	1.2	2.7
1980	69.6	23.8	3.0	3.7
1990	74.1	19.0	2.0	4.9
1991	73.8	19.4	2.0	4.8
1992	73.9	19.1	1.9	5.0

Sources: Jonathan E. Sinton, ed., *China Energy Databook* (Lawrence Berkeley Laboratory: 1992), II-8. Data for 1991 and 1992 are from *EIU Country Report No. 1 1993,* "China and Mongolia," 28.

Table 5. Annualized Growth Rates for Primary Energy Production

Year	Coal	Petroleum	Natural Gas	Hydro-electricity	Total
1949-1970	12.1	30.3	32.7	17.5	13.2
1970-1980	5.8	13.2	17.4	11.0	7.5
1980-1986	6.3	3.6	-0.6	8.4	5.6
1986-1992	3.4	1.4	2.0	5.5	3.1

Sources: Jonathan E. Sinton, ed., *China Energy Databook* (Lawrence Berkeley Laboratory: 1992), II-6; Data for 1991 and 1992 are from *EIU Country Report No. 1, 1993,* "China and Mongolia," 28.

Table 6. Crude Oil
(thousand barrel/day)

Year	Production	Imports	Exports	Net Exports
1985	2,498	N/A	601	N/A
1986	2,614	9	570	561
1987	2,680	N/A	545	N/A
1988	2,740	17	521	504
1989	2,752	65	488	423
1990	2,760	58	480	421
1991	2,792	119	452	333
1992	2,840	227	430	203
1993	2,900	313	389	76

Source: "China's New Oil Import Status Underpins World's Most Dynamic Petroleum Scene," *Oil and Gas Journal* (May 9, 1994), 34.

Energy Outlook in the Newly Industrialized Asian Countries

Fereidun Fesharaki

LET US START BY EXAMINING the energy consumption structure in the Asia Pacific region. Overall in the world, oil use constitutes about 40 percent of total energy demand, and in Asia Pacific, it is about the same. However, gas supplies about 23 percent of energy demand in the world, while gas consumption in the Asia Pacific region is very small, largely because China is such a small consumer of gas. The share of coal in the world is about 28 percent, and in the Asia Pacific region it is about 47 percent; again, much of that is because of the overwhelming share of China, which accounts for much of the coal consumption in the region. Regarding nuclear and hydropower, Asia Pacific is not terribly different in its pattern of consumption from the rest of the world.

In regards to environmental concerns, you can try to stabilize CO_2 emissions at 1990 levels here or there, but in the larger scheme of things, it makes no difference as long as countries like China continue to grow and to increase their use of fossil fuels. Many groups from the Asia Pacific region who host experts from the United States and Europe who tell them what to do about such emissions secretly laugh. They believe that they are being asked to do something that is impossible; their attitude is that they will sign any convention as long as someone else is prepared to pay for it. Except for the Japanese, who play the role of the

---

Dr. Fesharaki is the Director of the Program on Resources, East-West Center, Honolulu, Hawaii. His area of specialization is oil and gas market analysis and the downstream petroleum sector. He has been an adviser to a number of major oil companies, utilities, mining companies, shipping/storage firms and governments in the Middle East, Pacific basin and Latin America, as well as the U.S. Government. Dr. Fesharaki is the author of more than 70 papers and has authored or edited 23 books and monographs.

industrialized rich club, the rest of the region really sees carbon emissions as a U.S. and European problem. Rhetorically, they will nod their heads in assent to some extent, but to seriously expect countries of the Asia Pacific region in general and China in particular to commit economic suicide in order to uphold the targets of the Rio Convention and other such targets is not realistic.

To bring the same point home, consider Asia Pacific's electricity generation, which is set to grow from about 500 gigawatts to something like 1400 gigawatts by 2010. Oil is only a small part of electricity generation capability. Nuclear power is increasing significantly, as is gas. But again, the basis of electricity generation in the region will remain coal, with China playing a leading role. Every 6 months, the Chinese need a world-scale refinery; every 2 weeks, they need a 500-megawatt power plant. This will result in continuous pressure on energy supply and a need to find energy sources to generate electricity. The transportation problems constitute an additional set of challenges.

Let us now take a look at demand for petroleum in the Asia Pacific region. Asia Pacific has now become the epicenter of future growth in oil consumption. Demand grew by 6.7 percent in the region in 1993. In 1994, we're looking at 5.4 percent growth, an annual increase of 800,000 barrels per day to world oil demand. The demand for oil is growing fastest in China, Korea, Vietnam, Thailand, Indonesia, and India, with China alone adding a quarter of a million barrels per day to the world oil demand annually. It is interesting to note that what the Chinese add is likely to be almost equal to the drop in U.S. oil production for the foreseeable future. So if you add 250,000 there and subtract 250,000 here, the net effect on the need for trade in world markets is equal to about half a million barrels per day in itself.

Between 1994 and the year 2000, we expect 3.5 to 4 million barrels per day of additional oil demand to be generated in the Asia Pacific region. If you look at the estimates of maybe 6 or 7 million barrels per day of growth in world demand for oil, with 3.5 to 4.0 million coming from Asia Pacific and another 1.0 million or so coming from Mexico and Brazil alone, the rest of the world will not really matter in bringing the demand for OPEC oil to 30 million barrels per day. Increases in Asia Pacific, OPEC's own consumption, and Mexico and Brazil will suffice to bring world demand to this level by the year 2000.

In 1990, world oil demand grew by 725,000 barrels per day, while Asian growth was 720,000. Without Asian growth, there would have been essentially zero growth in the world. Overall, since 1990, world oil demand has increased by 500,000 barrels per day, and Asia Pacific demand has increased by 3 million barrels per day. The 3.5 to 4.0 million barrels per day of growth between now and the year 2000 may well be an underestimate, because every year, we say that the rates of growth we have seen in recent years can't go on and must slow down—but every year, it keeps growing. Indeed, 1994 has seen a very fast rate of consumption growth. 1995 perhaps will be slower, but the figure of an additional 3.5 to 4.0 million barrels per day by 2000 is actually the conservative estimate; it could be much higher than that. Why is demand growing so fast in the Asia-Pacific region? There are three main reasons. One, of course, is the fast rate of GNP growth in the region. The second is that the price of oil is cheap, by all standards. It is cheap in dollar terms, but it is particularly cheap in terms of the currencies of some of the countries in the region, which have appreciated against the U.S. dollar. Consider the real price of Arab light in terms of U.S. dollars and Japanese yen per barrel. In yen, the price of oil is about $2.50 per barrel in 1980 prices. In U.S. dollars, the price of oil is double that (at 1980 prices). In terms of purchasing power capability, the price of oil to the Japanese is very, very low, as it is to the Koreans and Taiwanese. Of course, not everyone's currencies have gained against the U.S. dollar, but some of the larger economies have made a great deal of gain.

Third, many of the Asia Pacific countries have gone through deregulation, and getting rid of price stabilization plans has reduced the price of oil. South Korea provides an interesting example. In 1985, the price of a barrel of oil was in the mid-to-high twenties. The South Korean government decreed that whatever price you paid for oil on the market, you have to pay the difference to bring it to a $34 limit, and they created what they called a petroleum business fund, hoping that when the price went above $34, they could use this fund to subsidize the market—one of those bad schemes that have backfired everywhere. What has happened since then? The price of oil has gone down significantly, in real terms. The petroleum business fund is gone; no one has to pay more than the market price. The South Korean currency has gone up 50 percent against the U.S. dollar, and the

GNP growth rate has been very high. If you put all of this together, you get a force that has led to this incredible explosion of demand. And still we say, how long can this sort of growth last? Certainly, it is not going to stop in the next few years. But whether it will continue until 2010 or 2020 at this speed is doubtful.

Let me now say a few words to you about import dependence in the region, and try to draw some comparisons between what we see in Asia and the United States. Asia Pacific oil production is likely to remain stable, or even slightly increase, but those who are big producers of oil are also big consumers. China became a net importer of petroleum in 1993, and estimates indicate a minimum net inflow of 1.3 million barrels per day to China by the year 2000. Our estimates, coincidentally, are the same for India; India and China will be the two largest importers of oil in Asia, not only in terms of volume, but in terms of the change in one decade. For the entire region, the level of imports will be substantially larger.

Much of this oil will have to be imported from the outside. If you have growth in demand for oil of 4 million barrels per day, and you are already using most of the oil that you produce yourself, imports are inevitable. In 1993, over 55 percent of total oil consumption in the region was imported; we expect this to rise to 68 percent by the turn of the century—not very different from what U.S. import dependence will be. However, within the region, there will be large variations. The dependence of the Japanese, as well as the Koreans and Taiwanese, is very high. While some East Asians have certain concerns about the growth in their imports of oil, I don't believe that discussions about limiting oil import dependence heard in the United States have been heard there. The East Asians realize that it is something that they have to live with, and the best way to do this is to pay for it. The general attitude therefore seems to be that if they work hard and have the money to pay for oil, they do not have to worry about energy security or supply.

About 65 percent of Asia Pacific's imports come from the Persian Gulf. By the year 2000, with import dependence at two-thirds of demand, over 90 percent, perhaps about 95 percent, will have to come from the Persian Gulf. So import dependence, which until recently has been partly on Latin American and African sources,will be very much concentrated on the Middle East. This

is something that the countries of Asia Pacific are contemplating, and they believe they can live with it.

What does this mean in terms of changing political and economic alliances? I'm not terribly concerned by any implications that it may have in terms of military confrontation. But it does have important political and economic implications when the center of gravity in terms of additional demand for energy is shifted from the U.S. and Europe to Asia. We should not be surprised, for example, that Saudi Arabia has now taken a great interest in investing in East Asian refineries. 500,000 barrels per day of crude imports are now committed to Korea alone by Saudi investments. The Saudis have taken a major share of oil refining capacity in the Philippines, which will commit them to 150,000 barrels per day, to be expanded to 300,000. In addition, a Saudi investment in expansion of a refinery in southern China, which should give them another 250,000 to 300,000 barrels per day,is under active negotiation. By the end of this decade, the Saudis will have committed oil supplies of well over 1 million barrels per day for refining to the Asia Pacific region.

Consider Asia Pacific imports from the Middle East. Between 1992 and 2000, the changes will be quite large. In China, the growth is from almost nothing to over 1 million barrels per day, compared to overall imports of 1.3 million barrels per day. Indonesia is looking at about 300,000 barrels per day of imports from the Persian Gulf; India will be importing an amount about equal to China's; South Korea, Taiwan, Thailand and others will also be major consumers of Persian Gulf oil. The picture is changing very rapidly, and much of this change will happen in this decade. By the beginning of the next century, we will see a significantly altered landscape in terms of trade relationships.

The situation is not as radical in terms of natural gas imports, but it is also very significant. In the Asia Pacific region today, importers are Japan, Korea, and Taiwan, and suppliers are Alaska, Australia, Brunei, Malaysia, Abu Dhabi, and particularly Indonesia. Both imports and exports fall in the range of just under 50 million tons per year. As we move toward the future, the demand for liquified natural gas (LNG) becomes more insatiable. Our projections show the demand for LNG increasing from 40 million tons or so in 1992-1993 to 110 million tons or so by the year 2010—almost a tripling. By the year 2000, we expect to see about a doubling of demand from 1992-1993 levels. We see India, China,

and Thailand joining the ranks of regional LNG importers, along with the current buyers Japan, Korea, and Taiwan. China does have natural gas reserves, but they are in inconvenient places; a lot of gas is found in the Sichuan province, as well as in offshore locations. Above all, they need it in Shanghai, and that is where negotiations are continuing with the view of obtaining gas from Qatar.

Turning to potential suppliers of gas in the region, some of the old players mentioned above are still there, but more and more, Asia Pacific's sources of LNG will be found in new areas such as Qatar, Oman, Yemen, and the Sakhalin Islands. Taking everything together, based on what the Asians need, significant shortfalls of gas contracts exist. That doesn't mean an actual shortfall of gas, but new contracts have to be signed in the next 2 to 3 hree years to ensure gas will be available. Almost all these contracts will have to come from the Persian Gulf, in the first instance from Qatar and Oman, before expanding supplies from the Asia Pacific region will be considered.

In short, the upward trend in energy demand in the region is very strong. The impact on U.S. security of this trend will arise from its effects on the world oil market. The countries in the region are a little nervous, but they find that establishing bilateral relationships with suppliers and maintaining strong economies assures access to the supplies they need. While the imports of China and India may not have a dramatic impact on world crude oil markets *per se*, because they are not building refineries fast enough, they will be importing a high proportion of refined products there. As importers of refined oil products, they could have a substantial impact on the world refined petroleum market.

The Woeful State of Saudi Finances

Eliyahu Kanovsky

IN EVERY YEAR SINCE 1983 there have been budgetary deficits, in sharp contrast with the large surpluses of the previous decade. Between 1983 and 1992 the *cumulative deficits* amounted to $141 billion; in the previous decade the *cumulative surpluses* had been $107 billion. The balance of payments (the current account) shows a similar trend going from a cumulative surplus of $163 billion in 1973-82 to a cumulative deficit of $138 billion in 1983-92.[1] 1993 data are not yet available, but there is little doubt that deficits persisted. It should be stressed that the reference here is to state finances, not the private accounts of the extended royal family and some other wealthy Saudis.

In mid-1993, an IMF mission that visited Saudi Arabia made 5-year projections for 1993-97. The mission projected that annual budgetary deficits would rise from $6 billion in 1993 to $11 billion in 1997. State borrowing to cover the deficits would raise the total public debt from the equivalent of 56 percent of GDP in 1992 to 77 percent in 1997. Annual interest payments on the debt would rise from 7.3 percent of total government expenditure in 1992 to 11.8 percent in 1997. As for the balance of payments, the cumulative current account deficits in 1993-97 would amount to a massive $73 billion, even greater than the $68 billion deficit in the previous 5-year period which had been adversely affected by the Persian Gulf war of 1990-91.[2] In short, the IMF mission envisaged a further deterioration in Saudi finances.

Dr. Kanovksy is professor of economics and senior research associate at the BESA Center for Strategic Studies at Bar-Ilan University in Israel, and the Ludwig Jessleson Visiting Professor of Economics at Yeshiva University in New York. Dr. Kanovksy is the author of numerous studies of the economies of the Middle East and has been a consultant on Middle East economies to a variety of U.S. government agencies.

How were the budgetary deficits financed? Between 1983 and 1987, the treasury drew on the financial reserves accumulated during the "Years of Plenty." Subsequently, borrowing was mainly internal, from the commercial banks and pension funds. Since the Gulf war of 1990-91 there has been increasing recourse to foreign loans. The public domestic debt climbed from zero in 1987 to $74 billion at the end of 1993 and the external debt to $20 billion.[3] Saudi Arabia's gross domestic product (GDP) was an estimated $121 billion in 1993.[4] The major state enterprises which during earlier periods had been obtaining cheap finance from the state treasury, have had to turn to commercial banks, domestic and foreign.

The Saudi Financial Mess

In large measure, Saudi Arabia's current financial problems stem from the policies it adopted in the 1970s and early 1980s, when it was convinced that the oil boom would last into the indefinite future. It accepted at face value the almost unanimous view of oil analysts that oil prices would continue to rise and the demand for Saudi oil would continue to grow, at least until the end of the century. In other words, Saudi Arabia would continue to enjoy the best of both worlds, both higher prices (even when measured in constant, inflation-corrected dollars) and a growing volume of sales. The inexorable growth of oil revenues would greatly exceed the precipitous rise in public expenditures, and financial surpluses would continue to be the norm. Financial assets (largely held abroad) would continue to accumulate. These were the comforting projections of most analysts. Based on projections of growing need for Saudi oil U.S. officials attempted to persuade the Saudi authorities to expand productive capacity to far higher levels in order to reduce future oil shortages. In those days financial experts were terribly worried about the problem of "recycling" the enormous financial surpluses that some OPEC countries would presumably accumulate, especially Saudi Arabia, the world's largest oil exporter and the owner of one-fourth of the world's oil reserves. Reflecting these perceptions the preamble to the Saudi Development Plan for 1980-85 (announced in 1980) asserted that "The Kingdom is now one of the world's foremost financial powers, in addition to its role as the major oil exporter of the free world."[5]

Following the oil shock of 1973-74, Saudi public expenditures rose precipitously from $2.6 billion in 1972-73 to $43.7 billion in 1978-79. Despite the sharp growth in oil revenues, expenditures rose even more rapidly. Fiscal deficits emerged in 1977-78, and again in 1978-79, but the deficits were short lived. The very sharp rise in oil prices following the Iranian Islamic revolution in 1979,and the vast increase in oil revenues again yielded very large Saudi financial surpluses, swamping the deficits of the last years of the 1970s. It is important to stress that, perceptions notwithstanding, the oil shock of 1979 had nothing to do with OPEC or Saudi power to influence the market. The Islamic revolution, as well as the Iran-Iraq war of 1980-88, were exogenous shocks to the market neither foreseen nor planned by OPEC or the Saudis. Of course, both OPEC and non-OPEC oil exporters took advantage of the far higher prices to augment their treasuries.

Just as in the 1970s, the vast influx of oil revenues in 1979-81 was soon followed by a further expansion of Saudi public spending, almost doubling from $43.7 billion in 1978/79 to $83.7 billion in 1981/82. In the short run, the expansion of spending, as large as it was, lagged behind the precipitous rise in oil revenues, and large financial surpluses emerged. But then the unexpected occurred: oil prices began to soften and demand for OPEC oil declined sharply. Since Saudi Arabia had undertaken to be the swing producer in the cartel, demand for Saudi oil dropped even more sharply. The decline in Saudi oil export revenues that ensued was precipitous, from a peak of $11 billion in 1981 to $45 billion in 1983, and lower in the following years. Saudi deficits emerge and persist to this date. There were, of course, price fluctuations, but the overall price trend during the 1980s was lower, until the Persian Gulf war of 1990-91 reversed the downtrend temporarily .[6]

Faced with sharply lower revenues, the Saudi authorities began to implement spending cutbacks. By far the severest cuts were in the projects budget, mainly the building of infrastructure (roads, ports, airports, power and water, telecommunications, health and educational institutions, etc.), which dropped sharply from a peak of $35 billion in 1981 (about half of state expenditure) to an annual level averaging $12 billion in the latter half of the 1980s. (The projects budgets do not include operations and maintenance, which cost an additional $6 to $7 billion annually). The cutbacks in the projects budget affected mainly foreign contractors and their labor force, which is almost all foreign. Aid

to the poorer Arab countries, which had peaked at over $7 billion annually in the early 1980s, was sharply curtailed to less than $2 billion per annum in the later 1980s. (These figures do not include off-budgetary financial aid to Iraq in its war with Iran, 1980-88). The military budget was officially cut from $18-19 billion in 1981-84 to $14 billion in 1985-89 (annual averages). However, these figures are somewhat misleading because there are very large off-budgetary military expenditures, in particular the agreement with the United Kingdom for arms imports in exchange for oil shipments of 500 thousand barrels per day.[7]

What is most important is that a whole range of subsidies, current expenditures on civil service salaries, and other state spending that might affect the citizenry were hardly touched. During the heyday of massive oil revenues the Saudi authorities were profligate in their spending on what could be broadly called social welfare. This includes free health and educational services, up to and including graduate studies at universities, noninterest bearing loans for housing, and highly subsidized rates for electricity, water, and other utilities. Gasoline and other refined oil products were sold domestically at a fraction of international prices. Producers, especially in industry and agriculture, also enjoyed a wide range of grants and noninterest bearing loans, and various kinds of financial support. While subsidies (direct and indirect) are not uncommon in many countries, their magnitude in Saudi Arabia has few, if any, parallels (as a ratio of GDP). The development of nonoil industries and of modern agriculture, is virtually dependent on large-scale subsidization, as well as on an overwhelming foreign labor force. According to one scholar subsidies, direct and indirect, explicit and implicit, rose from 4 percent of total government spending in 1975 to 72 percent in 1984, or alternatively, from 4 to 68 percent of oil revenues.

Saudi high school and university graduates expect white collar jobs in the state bureaucracy. The large majority of employed Saudis is on the bloated state payroll. This, too, constitutes a serious and growing drain on the state treasury. The system of "kickbacks and commissions" mainly benefiting some 10,000 royal princes and others close to the royal family is another serious drain on the state treasury. Of course, these do not appear in the official budgets; an estimate quoted by a reputable journal suggested that these were as high as $10 billion per annum[8] Saudi oil export revenues in 1993 were $40 billion. Even if these

"commissions" are only half of the above estimate, they exacerbate the state's fiscal problems. Other than limited revenues from customs duties and fees, the state treasury is largely dependent on oil revenues. There is powerful resistance to taxation. Given the far lower level of oil revenues since 1983, and the downward inflexibility of expenditures (following the cutbacks in the projects budget and in foreign aid), the inevitable result was a string of large budgetary deficits covered initially by drawing down the financial reserves, followed by borrowing since 1987. Instead of substantial revenues from foreign investments, the treasury is faced with an ever-growing public debt. Servicing the debt (payment of interest and principal) has become increasingly onerous.[9]

The Persian Gulf War and its Aftermath

The Persian Gulf war of 1990-91 made a bad situation worse. The U.N. embargo of Iraqi oil, as well as the destruction of Kuwait's oil facilities, raised oil prices temporarily and also permitted the Saudis to expand the volume of oil exports. Oil export revenues rose from $24 billion in 1989 to $44 billion in 1991. However, war-related expenditures rose far more rapidly, including payments to the United States and other allies, as well as higher local Saudi military expenditures. According to Saudi budgetary reports military and "emergency" expenditures in the 3-year period 1990-92 were $76 billion. Government oil revenues in that period were almost $100 billion, as compared with $50 billion in the previous 3 years. The downward inflexibility of civilian expenditures is underscored by the fact that despite the dire threat to Saudi Arabia the authorities made no attempt to curb civilian expenditures or to impose taxes to help pay for the war. In fact, about a year after the war, the king announced a whole range of price reductions of gasoline, natural gas, electricity and water. Charges on domestic telephone calls were eliminated, and various business charges were reduced.[10] These measures entail an increase in the already high level of subsidies. Moreover, it implies an even more rapid growth in consumption. This, in turn, entails additional expenditures on electric power stations, water supplies and telecommunications, in order to forestall supply shortages. Not surprisingly, the rise in demand for electricity in the past 2 years (since the king's announcement of lower prices) has been

described as "dramatic." It has been estimated that the growth rate of demand between 1993 and the year 2000 will be 15 percent per annum, requiring a 70 percent expansion of electric power capacity, at a cost of $15 billion between 1993 and the year 2000. Saudi electric companies are seeking loans from the United States and the United Kingdom to finance the investment.[11]

The impact of the war will be felt for many years. Between mid-1990 and mid-1993, the Saudis placed orders for $30 billion of U.S. military equipment, in addition to large orders from the United Kingdom and smaller orders from other suppliers. The Iraqi threat, fear of Iran, and border disputes with Yemen, Qatar and others have persuaded the Saudis to greatly expand their armed forces and equip them with the most sophisticated and expensive weapons.[12] According to the U.S. Arms Control and Disarmament Agency, Saudi arms imports in the 5-year period 1987-91 amounted to $30 billion, exceeding by far all other countries, including Iraq ($16 billion) and Iran ($9 billion). Syrian arms purchases abroad were $6 billion, followed by Israel ($5 billion) and Egypt ($4 billion). The hugh military orders placed by Saudi Arabia since the 1990-91 war will probably ensure its continued dubious distinction as the world's largest arms importer. Further, in the 1987-91 period, the United Kingdom supplied over one-half ($16.3 billion) and the United States about one-sixth ($5.1 billion) of total Saudi weapons purchases. The new orders placed since the war mean that the United States will be the prime Saudi arms supplier. As a consequence of the war, Saudi Arabia has greatly expanded its armed forces, from about 80,000 throughout the 1980s, to 191,000 in 1991.[13] What is abundantly clear is that the massive arms acquisitions and the major expansion of the armed forces will require a large long-term increase in Saudi Arabian defense spending on the construction and expansion of military bases, maintenance, spare parts, ammunition, training, housing, and services for the members of the armed forces and their facilities, etc. If Saudi defense expenditures were unusually large in the 1980s (averaging 18 percent of GDP), they will be substantially greater in the foreseeable future.

Closely related to the budgetary deficits are the current account, balance of payments deficits which have persisted since 1983. A Washington-based consulting firm projects that these will continue in 1994-96, raising the external debt to over $37 billion by the end of 1996, about twice that of 1993.[14] This projection is

based on the assumption that U.N. sanctions on Iraqi oil exports will continue during this period. If they are rescinded or eased, the outlook for Saudi Arabia is even more pessimistic.

Can Saudi Arabia Cope with the Financial Crisis?

In apparent response to the deepening fiscal crisis the announced budget for 1994 called for a 19 percent cutback in spending, as compared with 1993. If achieved this would be close to a balanced budget—i.e., a deficit of a little more than one billion dollars, as compared with an estimated deficit of $7.5 billion in 1993.[15] However, the announced budget does not take into account servicing of obligations already undertaken, notably payment for the $30 billion in military equipment from the United States. Payments due to U.S. arms suppliers in 1994 plus 1995 were $9.2 billion, and the Saudis were unable to meet these obligations. In order to forestall a sharp reduction in military sales, the U.S. administration arranged for a restructuring that reduces Saudi payments to the arms manufacturers to $1.5 billion in 1994 and again in 1995. The balance of over $6 billion due in 1994-95 will be covered by loan guarantees by the Saudi government, which will also pay interest. The loans will formally be taken by a new corporation (set up for this purpose) that will be the borrower from U.S. commercial banks. Through this method the debt will not appear in the Saudi accounts.[16]

In spring 1994 the Saudis signed a $4 billion contract with AT&T for the modernization of the phone system, and the state-owned airline signed a $6 billion contract for the purchase of civilian aircraft. In both cases, the Export-Import Bank will provide the bulk of the financing.[17] In addition to these and other loans, the Ministry of Finance has been following a policy of very lengthy delays in payments to contractors, mainly foreign, operating in Saudi Arabia. Some contractors complain of a 15-month delay.[18] In effect, the contractors have become unwilling lenders. Payment delays from the treasury are also seriously affecting Saudi businesses .[19]

These measures—continued large-scale borrowing and payment delays—do not attack the underlying financial and economic problems. This would require far-reaching radical changes, and there is no indication of such changes taking place. These would have to include the impositions of taxes, and/or sharp

cutbacks in subsidies, military expenditures, "commissions and kickbacks," and the bloated bureaucracy. The state directly employs some 90 percent of Saudis in the labor force. In effect such measures would raise prices substantially and significantly reduce living standards. The population at large and Saudi businessmen in particular strongly resist such measures, and the extended royal family resists the curtailment of its privileged lucrative position.

The growing fiscal problems in the past few years have already had some impact on Saudi living standards. In 1989, the U.S. Embassy in Riyadh reported that "unemployment is emerging as a serious problem." The reference is to high school and university graduates who "have expectations based on the boom years, not present realities".[20] There are millions of foreigners working in Saudi Arabia, but most Saudi graduates refuse to accept jobs involving manual or other "demeaning" labor, accepting only white collar jobs. According to one estimate published in 1993, the unemployment rate among graduates had reached 25 percent.[21] While the government has not fired state employees, financial stringency has sharply restricted new hiring, while more graduates enter the labor market every year.

Official figures show that average living standards (measured by real private consumption per capita) rose very sharply, actually quadrupling between 1973 and 1982. Subsequently there was an erosion, with living standards dropping by about one-sixth between 1983 and 1992 .[22] Anecdotal evidence lends credence to these figures. One report notes, "There are long queues for (interest-free) housing loans; (recent) graduates no longer command (state) jobs; unemployment is substantial; and some real poverty stalks the back streets of Jiddah and Riyadh."[23] Another report notes that "years of mismanagement, corruption and budget deficits have left schools overcrowded and many young Saudis unemployed . . . many can afford little beyond basics . . . some Jiddah streets get water only two days a week . . . doctors often deliver babies in the emergency room because hospital bed are scarce . . . across Saudi Arabia fundamentalism is particularly strong among the young."[24] "Economic troubles are in sharp contrast with the opulent life of the royal family who number in the thousands. The practice of taking up to 30 percent commissions, and other facets of corruption are (now being) more readily criticized as are the ostentatious life styles of the princes."[25]

And yet another report notes the rising discontent that is accentuated by the practices of the princes who "commandeer free seats for themselves and their retinue on Saudi airlines, or import goods without customs clearance . . . muscle in on commoners' profitable enterprises," and engage in other unsavory practices.[26] The princes also do not pay for water, electricity, and telephone services.[27] Moreover, Saudi banks are forced to lend to members of the royal family who often fail to repay. There are billions of dollars in uncollected loans owed by the princes to the commercial banks. When asked why they lend money to the princes, an (unnamed) Saudi banker responded that the banks "had to respect the wishes of an absolute monarch."[28]

Radical measures to curb spending and/or impose taxes are severely constrained by the lavish incomes and lifestyles of the thousands of princes and some others close to the royal family. It is politically almost impossible to expect the ordinary citizen to acquiesce to lower living standards while the royal family and other wealthy Saudis live ostentatiously,and instead of paying taxes continue to drain the state treasury. There are no figures on income distribution, but all indications are that the income gap has widened considerably in the past decade. All these developments spell trouble ahead for the regime.

The policy of the regime can be summarized as trying to "muddle through" in the hope that external events will extricate the state from its growing crisis. In other words, the government hopes that external events—wars, revolutions, or other disturbances in other oil-exporting countries—will allow the Saudis to increase their oil revenues substantially either through higher oil prices or a greater volume of oil exports, or both. In the interim, the government is trying to avoid or at least postpone politically difficult decisions by incurring more and more debt. But barring sharp and painful cutbacks in public and private consumption, state expenditures and imports will inevitably rise. As one analyst phrased it before the 1990-91 war, "The real problem is that the country has, since 1973, locked itself into what appears an inflexible situation with very little room for maneuvre."[29] The 1990-91 Gulf war has greatly aggravated the country's financial problems, both present and future. Moreover, "Spending on education, health and social welfare will rise inexorably in the coming years (barring radical changes in policy, since) the population is growing by over 3 percent per annum. (Moreover) . . . an ever larger

proportion of government resources will have to be devoted to servicing the growing official debt. . . . It will be far from easy to break out of the self-perpetuating circle. Uncomfortable choices will have to be made at some stage. The alarming thing is that the government seems to display no interest in tackling the issue".[30]

Future Prospects

My own analysis leads to the conclusion that the underlying longer term trends point to low or lower oil prices, at least when measured in constant dollars.[31] There will most probably be price fluctuations due to seasonal factors, the state of the world economy, especially in the main oil-importing countries, and, of course, wars, revolutions, and other supply disruptions. This was the case during the recent Persian Gulf war when prices shot up very briefly from less than $20 to over $40 a barrel. But following these shocks, economic forces stimulate greater outlays on exploration and development worldwide and also curb demand. Within a relatively short time, the application of new technology expands supply and restrains demand. Average prices in 1993 were $16.13, compared with $17.19 in 1989—a decline of 6.2 percent measured in current dollars; in constant dollars the decline was about 15 percent. [32] I anticipate that average 1994 prices will be even lower.

While future oil shocks may temporarily raise prices ,there are political developments that may well put strong downward pressure on oil prices. One can anticipate that during the coming years the U.N. sanctions on Iraq will be removed or at least eased. Iraq's oil reserves are second only to Saudi Arabia's, and its motivation to exploit them fully and quickly has never been greater. It has gone through a very costly war with Iran, the devastation of the Persian Gulf war of 1990-91, and over 4 years of increasingly painful sanctions. When these are rescinded, Iraq is not likely to restrict output, regardless of OPEC quotas.

Another important factor sustaining or raising prices in the past 6 years has been the very sharp decline in Russian oil production since 1988. By all accounts the oil potential of Russia and of some of the former Soviet republics is vast. Foreign oil companies have flocked to the former Soviet Union seeking to exploit these resources. But, internal political problems have severely hampered their efforts as well as the performance of the Russian

oil companies. There are indications, however, that these problems are beginning to be resolved. Soviet oil exports that had been dropping have stabilized. In mid-1994 the Deputy Oil Minister projected that oil exports will rise in 1994.[33] A continuation of these trends will put additional downward pressure on oil prices.

Petroleum Intelligence Weekly notes that technological changes have sharply lowered the costs of production. The average cost of finding and developing new oil reserves has been halved since the early 1980s, to about $10 a barrel. [34] "OPEC's main problem is the sharp fall in costs of exploration and development worldwide." Moreover, in many countries, higher taxes, imposed for environmental and/or fiscal reasons, are offsetting the effect of lower oil prices on demand. "The implications are profound, even revolutionary . . . yet most Middle East governments still live in a dream world (believing) . . . oil riches are limitless".[35]

Saudi oil policy is greatly influenced by its experience since the early 1980s. It opposes significantly higher prices because they strengthen economic forces that restrain demand and expand worldwide supplies. Because Saudi oil reserves are huge—and it has not succeeded in reducing its overwhelming dependence on oil revenues—it is more concerned than other oil-exporting countries with the longer run trends. Moreover, Saudi authorities point out that if their country cuts back significantly on output, other OPEC members with unutilized capacity would "cheat" and increase their share of the market at the expense of Saudi Arabia.[36]

In view of the growing fiscal crisis in Saudi Arabia, and the poor prospects for a substantial increase in oil revenues (barring external shocks), the crisis can only worsen, and there are reports of growing unrest. A recent book by Said Aburish, *The Rise, Corruption and Coming Fall of the House of Saudi* (Bloomsbury Publishing, London 1994), anticipates the collapse of the Al-Saud family on the grounds that internal, regional and international problems threaten their role because "the Kingdom is a patriarch with exclusive dependence on money to buy its way out of trouble." "The Saudi financial crisis severely hampers the ability of the regime to pursue a policy of "riyal diplomacy" either internally or internationally. David Hirst concludes, "Saudi Arabia's inexorably deteriorating finances are symptomatic of a much wider malaise. . . . The long deferred but now seemingly inevitable end of the

great boom years, and the consequent erosion of a welfare system of unrivalled munificence . . . combined with the rise of its own exotic brand of fundamentalism . . . could prove a dangerous mixture."[37] *The Petroleum Economist* concludes that "faltering economies bode ill for the future of the Gulf states . . . as the Saudi economy gets worse, and local purchasing power falls . . . political pressures are increasing."

Implications for U.S. Policy

Forecasting is a hazardous occupation, but U.S. oil policies should take into account the serious possibility of revolutionary changes in Saudi Arabia that may entail a temporary curtailment of Saudi oil exports. Speculative fever would raise prices very sharply, but the United States, together with its allies, could reduce the price hikes by the prompt utilization of their Strategic Petroleum Reserve (SPR). Following the invasion of Kuwait in August 1990, the U.S. administration waited a number of months before announcing the use of its SPR; the United States should be prepared to utilize it without undue delay. Other industrialized countries should be urged to do the same.

A number of major industrialized countries have been raising taxes on gasoline and some other oil products for fiscal and/or environmental reasons, in order to dampen demand. In this respect the United States has been laggard because of domestic political problems. Because the United States alone accounts for one-fourth of world oil consumption, and gasoline accounts for close to one-half of its oil consumption, a change in U.S. policies—even a modest rise in taxation—would have a strong effect on world oil markets.

A greater worldwide diversification of oil supplies would substantially reduce the impact of future supply disruptions, especially from the Persian Gulf countries, and in fact this has been occurring. Excluding OPEC, the United States, and the former Soviet Union, there has been a steady but substantial growth in output. In this broad group of countries (mainly the less-developed countries in Asia, Africa, and Latin America, as well as North Sea output), the rise has been significant (in millions of barrels per day), from 7.6 in 1973 (about that of Saudi Arabia) to 15.6 in 1983 (compared with Saudi output of 5.4) and 21.8 in 1993 (compared with 8.7 in Saudi Arabia).[38]

Much of this increase in recent years has been because of a change in policies in many less-developed countries, who now welcome foreign oil companies. The latter have both the resources and the technology needed to find and develop oil (as well as gas) resources. Expanding World Bank facilities for the development of energy resources and their more efficient utilization in the less developed countries, would help to diversify world oil supplies, restrain demand, and reduce the impact of future disruptions. Technical and financial aid to Russia and some of the former Soviet republics to develop their energy resources and improve their efficient use, would, over time, provide additional insurance and weaken the effects of Middle East oil-supply disruptions. The United States may not be able to prevent future Saudi oil disruptions, but it can take steps to cope with them if and when they arise.

Notes

1. Unless otherwise stated, all data are from Saudi Arabian Monetary Agency *Annual Reports* and the International Monetary Fund, *International Financial Statistics.*
2. Economist Intelligence Unit *Country Report-Saudi Arabia* no. 4, 1993, 21; *Middle East Economic Survey* August 9, 1993, B1-7.
3. The *Economist Energy Survey*, June 18, 1994, 15.
4. Economist Intelligence Unit *Country Report-Saudi Arabia*, no. 3, 1994, 3.
5. Kingdom of Saudi Arabia, Ministry of Planning *Third Development Plan 1400-1405*, 1980-85, 14.
6. For details and sources see my study, *The Economy of Saudi Arabia: Troubled Present, Grim Future,* The Washington Institute for Near East Policy, Washington, DC 1994.
7. Hoosein Askari, *Arabia's Economy: Oil and the Search for Economic Development*, JAI Press, 1990, 88-115.
8. *Petroleum Economist*, September 1993, 20.
9. The International Institute for Strategic Studies, *The Military Balance 1993-1994*, p. 127; Saudi Arabian Monetary Agency, *Annual Reports*; *Middle East Economic Digest*, November 6, 1992, 8 and April 30, 1993, 11.
10. *Financial Times*, March 25, 1992, 4.
11. *Middle East Economic Digest*, September 2, 1994, .6.
12. *Middle East Economic Digest*, May 6, 1994, 5.
13. U.S. Arms Control and Disarmament Agency, *World Military Expenditures and Arms Transfers 1991-1992* Washington, DC 1994, 79, 131-134.
14. *Middle East Economic Digest*, September 2, 1994, 6.
15. *The Economist*, January 15, 1994, 47-48.
16. *Wall Street Journal*, January 31, 1994, A2.
17. *Business Week*, May 23, 1994, 28-29.
18. *Petroleum Economist*, June 1994, 86-87.
19. *Middle East Economic Digest*, May 6, 1994, 4.

20. U.S. Department of Commerce, *Foreign Economic Trends - Saudi Arabia*, 1989, 6-7.
21. *Petroleum Economist*, September 1993, 20.
22. Calculated from data in International Monetary Fund, *International Financial Statistics*.
23. *Middle East Review 1993/94*, London, 1993, 1-3.
24. *Wall Street Journal*, January 13, 1993, A1, A8.
25. *New York Times*, February 14, 1993, 3.
26. *Middle East Review 1993/94*, London 1993, 1-3.
27. S. Henderson, *After King Fhad: Succession in Saudi Arabia*, The Washington Institute for Near East Policy, 1994, 42.
28. *New York Times*, August 22, 1993, 1, 12.
29. R.E. Looney, *Economic Development in Saudi Arabia: Consequences of the Oil Price Decline*, JAI Press, 1990, 145.
30. *Middle East Economic Digest*, April 30, 1993, 11.
31. For details and sources see my study on *The Economic Consequences of the Persian Gulf War: Accelerating OPEC's Demise*, The Washington Institute for Near East Policy, Washington, DC, 1992.
32. International Monetary Fund, *International Financial Statistics*, annual volume for 1994.
33. *The Economist*, July 16, 1994, 4.
34. *Petroleum Intelligence Weekly*, Jan. 3, 1994, 1,4.
35. *Middle East Economist Digest*, January 14, 1994, 4.
36. *New York Times*, April 3, 1994.
37. David Hirst, "Heads in the Sand," *Middle East Review 1993/94*, 1.
38. British Petroleum, *BP Statistical Review of World Energy*, June 1994, 5, and earlier issues.

Discussion: Energy and Oil Supply

Question: We have heard a lot of cautionary talk about reliance on Persian Gulf oil; do you see any optimistic scenario for oil supply in general and Saudi Arabia in particular?

Eliyahu Kanovsky: I am not a pessimist with regard to oil prices or oil supplies. On the contrary, I am an optimist. I did not discuss here the whole issue of Iraq, which is a potentially huge supplier of oil that, sooner or later, will come back into the market. As for the Russian situation, what is relevant to world markets is Russian oil exports, not production. And these exports seem to have stabilized in the last year or two, from what I have read.

When I talked about Saudi Arabia, I did not imply that they would deliberately cause a cutback in oil production. That kind of threat existed in 1973 but has not existed since that time. The current Saudi regime is very concerned with the problem of production—they fight for their quota within OPEC, and refuse to go below the 8 million barrels per day that was demanded by other members of OPEC at the time when there were surpluses and prices were threatened. What I did suggest was that there is a danger of implosion there— as well as in several other countries in the region—in addition to the danger of external enemies, which of course exists in that part of the world. That implosion could mean a temporary decline in production, because of civil war or something of that nature. I don't know; it may or may not. In 1964, the king was ousted by the royal family; this could happen again. Or the army could take over, or whatever.

But I don't believe that any of this would cause long-term disruptions in oil supply. In the long run, no matter who takes power, he's going to need money, and the money will come from oil. The whole development plan of the Saudis was supposed to bring about a diminished role for oil within, and diversification of, the Saudi economy. From that point of view, it has been a miserable failure. The existence of other industries in Saudi Arabia is dependent upon government subsidies—such as subsidies for water and electrical power, and zero-interest loans. These subsidies are, in turn, dependent upon oil revenues. Agriculture is a big mess there as well, in terms of the regime's goals. In the final

analysis, dependence on oil has not diminished over time—it has increased, and the leadership is aware of it. One has to be cautious about the possibility of internal disruptions that would affect the supply of Saudi oil, but this does not mean that the world would come to an end. What it does imply is that one might take certain precautionary steps that would weaken the effect of such an interruption.

If you take the non-OPEC world, excluding the two big producers—the former Soviet Union and the United States—you find a steady upward drift in production that over the past 20 years has amounted to a significant increase in the supply of oil from non-OPEC nations. Saudi production has not risen in that time; this is not because they are not capable of raising it, but because of other reasons.

Fereidun Fesharaki: I would like to make a comment on Dr. Kanovsky's paper. What he says about the Saudis' lack of fiscal responsibility actually applies to many countries—perhaps we could say the same thing about how Nigeria or Venezuela have managed their economies with their oil revenues. We could look at corruption in Indonesia, Nigeria, and many other countries. Therefore, I think that to single out and denigrate the Saudis as irresponsible, stupid, lazy bums who don't want to work is rather offensive. The Saudis have made their mistakes, and perhaps their fiscal problems will lead them to a more rational approach in the future. But the internal problems in Saudi Arabia are far less than the internal problems of, say, Egypt or Algeria. They will deal with them. I cannot comment whether the present regime will survive, but the Saudis do have an excellent company, Saudi Aramco—very professional, very competent, very capable. And they will be able to increase production significantly at costs of less than $2 or $3 dollars per barrel. In any case, they will remain a key, important ally for the United States and should receive the respect they deserve.

III. The Long-Term Outlook For Energy Security

Guy Caruso

TODAY'S TOPIC, ENERGY AND NATIONAL SECURITY, covers a broad area. I will first share with you the IEA's thinking on the general energy market trends that we expect to see over the next 15 years and try to anticipate developments beyond that time frame. Second, I will focus on the oil component of the energy mix in the next century, and draw some general conclusions. Finally, I will discuss some of the key policy implications for national security that likely will be associated with that background.

The changes in world primary energy shares over the last three decades of this century and through the first decade of the 21st century are not very great. By the year 2010, we expect to see slightly less coal and oil in the mix, and slightly more gas, hydropower, and renewables. The renewables contribution will remain fairly small. Changes during the remainder of the next century may be much greater.

Between 1971 and 1990, there was a pronounced shift in OECD use of oil, with substantial declines in industrial, commercial, residential, and power-generation use, accompanied by a large gain (6 million barrels per day) in oil use in the transport sector.

Guy Caruso is Director, Office of Non-Member Countries of the Paris-based International Energy Agency (IEA), where he is responsible for relations with non-member countries and oversees studies of energy-related developments in those countries. Previously he was Director, Office of Oil and Natural Gas Policy, Office of Domestic and International Energy Policy, U.S. Department of Energy.

Between 1991 and 2010, we expect to see small increases in OECD industrial use of oil, additional small declines in buildings and power-generation uses, and an absolute increase in transport use nearly as large as that seen in the previous two decades.

While the *share* of oil in total energy consumption has been falling, the *quantity* of oil consumed nevertheless has been rising steadily since 1983. The fast-growing non-OECD regions will account for a progressively greater share of world oil demand. Growth in global demand for oil will accelerate toward the end of our projection period in 2010, with demand increasing each years by almost 1.9 million barrels per day between 2005 and 2010—compared with an average increase of just over one million barrels per day in the 1990s. Within the OECD countries, the average annual increase in oil demand in the 2005-2010 period will be limited to 0.2 million barrels per day, a sharp decline from the 0.5 million barrel average annual increase in the 1990s.

On the supply side, OECD oil production is expected to begin declining, with the sharpest decline occurring in the United States. In most regions of the world, notably Asia, rising oil demand will not be matched by expansion of local production. Consequently, this demand will be met by rising oil imports. World demand will increasingly have to be met by production from OPEC countries, with most of the increase coming from the Middle East and Venezuela.

In the former Soviet Union (FSU), it may be possible to stabilize oil production by the mid-1990s at perhaps half the production level of the 1980s. The direct contribution of foreign companies to Russian production is expected to be moderate throughout the 1990s. However, a steady increase in FSU production is expected from the late 1990s onwards. FSU production is expected to slightly exceed 10 million barrels per day by 2010, which is still well below the historical peak of 1987-1988. The increase in FSU production is expected to roughly offset the fall in production of OECD countries.

Even with significant "reserve creep" and a great deal of good luck, it is highly likely that conventional oil's share of the energy mix will decline sharply through the next century. The challenge is for energy institutions like IEA and oil-producing and -consuming governments to work to assure an orderly transition to a less oil-intensive economy in the 21st century.

At the beginning of the century, world oil demand growth will be driven by GDP and population. Higher prices may constrain demand growth to some extent, but up to 2010, the balance of pressures favors more growth. At the end of the century, however, conventional oil consumption will very probably be lower than at the beginning. Unfortunately, this will not necessarily be an environmentally benign world—it may be one dominated by oil sands, fuels derived from coal, or other environmentally damaging fuels—but conventional oil will have a much smaller role in the market. What will be the forces at work in making the transition from an energy market driven by oil to one in which oil is a minor player?

The forces constraining oil demand include environmental and other policies that shift the fuel mix away from oil; improvements in technology and efficiency that mean less oil will be needed to achieve the same result; changes in lifestyles (less commuting) and the structure of the economy (less heavy industry) that will further reduce demand for oil; and the increasing availability and cost effectiveness of alternative fuels. Of course, some pressures will work in the opposite direction: for example, advances in production technology (better drilling, better seismic work, automated production facilities) will hold down the price of oil and make it more economically attractive.

A pattern of increasing international trade in energy will evolve throughout the next century, especially in natural gas and electricity, but also in oil. As already noted, trade in oil will have an increasing component of Middle East oil going to Asia as Asian supplies fail to keep pace with demand increases. OECD countries are expected to see reductions of domestic oil supply, coupled with slowly increasing demand. The consequences will include more oil imports by OECD and increasingly more from the Middle East and to a lesser extent from Latin America. Oil import bills will of course increase, because of the combined effect of higher volumes and higher prices.

The risks to energy security include large-scale market failure, price volatility, and supply disruptions. However the increasing centrality of market processes in allocating oil will serve to moderate potential and actual shocks through greater efficiency, improved transparency, and new instruments (such as futures and derivatives). The role for government policy will be largely

confined to maintaining amicable international relations, keeping emergency oil stocks, and hammering out effective collective security arrangements.

To enhance their energy security, IEA countries have agreed to hold oil stocks equivalent to at least 90 days of net imports. In practice, IEA members have met this commitment with an ample, though declining, margin. At present, IEA net-oil-importing countries have about 150 days of stocks. Should they decide to maintain the current ratio of stocks to net imports, IEA member states would have to increase stocks by about 40 percent by the year 2010—an increase of nearly 200 million metric tons. At today's prices, this would represent an investment of some $40 billion, which will have important budgetary consequences and require considerable political will, as well as the continued cooperation of industry.

Maintaining adequate stocks will be difficult enough for the IEA countries. Non-IEA countries with burgeoning oil demand may not be adequately equipped, in terms of stock holdings, to deal with a supply disruption. This could place an additional burden on IEA countries in an oil disruption situation.

IEA is in the process of reviewing its policy on stocks. Early, coordinated use of stocks is likely to be emphasized. There is a recognized need to be prepared to adapt flexibly to unpredictable potential disruptions, and to be more inclusive of non-IEA market participants, in particular those in the Asia-Pacific region. One possibility would be to include regional organizations such as APEC (in the Asia-Pacific region) and OLADE (in Latin America) in emergency preparedness planning, as well as consultations during actual disruptions. At the very minimum, there is a need to share information with all key market participants. Multilateral responses take time and diplomacy; issues of sovereignty and equity need to be carefully negotiated. Further, rapidly growing natural gas and electricity trade will add uncertainty to the emergency planning process in the post-2000 period.

Oil disruptions remain the biggest energy threat to national security. Geopolitical events, not market constraints, will be the likely cause of any such disruption. Two-thirds of the world's proven oil reserves are in the Gulf Region; thus, Saudi Arabia, Iraq, Iran, and Kuwait will remain the focus of energy security concerns well

into the next century. Transportation demand for oil will grow through the first decades of the next century, although in the long term, perhaps 30 years or more down the road, technological advances will lessen our dependence on oil.

The responses of non-OECD oil consumers to oil shocks in the next 10 to 20 years will be an increasingly critical factor in determining how such shocks play out and affect world energy markets and supplies. Moreover, because circumstances are in rapid flux and our ability to predict actual disruption scenarios is extremely limited, we must place an emphasis on maximizing flexibility and avoiding rigid response systems. Markets are resilient, but they hate uncertainty; governments should therefore give clear signals during oil supply disruptions.

IV. Nuclear Energy and Proliferation

The Future of Nuclear Energy In Electricity Generation

Robert Eynon

I HAVE BEEN ASKED TO SHARE with you the Department of Energy's projections for commercial nuclear power. In doing so, I will be drawing from information in our 1994 annual *Energy Outlook*, and our *International Energy Outlook*, both published in 1994. I will characterize the U.S. national forecast in somewhat greater detail, because I think that it is broadly representative of the situation that exists in developed countries around the world. The forecast we have prepared includes the effects of legislation such as the Clean Air Act amendments of 1990, as well as the Energy Policy Act of 1992 (EPACT). Those pieces of legislation do influence the projection, so it is important to note they are included.

Electricity sales in the United States grew at about 3.4 percent per year in the 1970s; this was considerably above the growth in the economy, which grew at about 2.7 percent. At that time,

---

Robert T. Eynon is the Chief of the Nuclear and Electricity Analysis Branch at the U.S. Department of Energy. Previously he worked for the General Research Corporation, where he provided analytic support to the U.S. Army in its personnel management systems, and for the Federal Energy Administration, where he participated in the development of analytic approaches to energy markets focused on coal and electric power. Mr. Eynon received the Department of Energy's Meritorious Service Award for his contributions to the accomplishment of electric power analysis programs in the Energy Information Administration.

electricity use essentially outpaced economic development. After the energy crisis of the late 1970s, the growth of electricity sales ceased to increase at the pace of the prior period, and we predict that reductions in the growth of electricity sales will continue in the future. Our reference case, in which the economy is growing at 2.1 percent annually, has electricity sales growing at 1.2 percent. (The latter growth rate may range from 1.0 percent in a low-growth scenario to about 1.5 percent when we assume higher economic growth.) This is a somewhat radical departure from what we have seen in the past; in particular, consider the relationship of electricity use to GDP growth, both historically and in the projected future. Essentially, our forecasts show a reversal of the relationship that held prior to the 1990s, in which electricity sales generally outstripped economic growth rates. Our projections are actually lower than those of other forecasters, because we have taken explicit account of the Energy Policy Act initiatives—technological improvements, efficiency standards, and so on—that reduce demand more than would have otherwise been the case.

Nonetheless, electricity use continues to grow at a strong pace, in part because we project that the price for electricity relative to other fuels will rise less rapidly, at an annual rate of about 0 .3 percent. By contrast, natural gas prices are expected to rise at an annual rate of about 1.7 percent for all end users, oil at a rate of about 0.8 percent, and coal at a little more than 1 percent—so relatively stable electricity prices make it attractive in comparison with other fuels.

If we look at the composition of demand for electricity, we see that all end use sectors are growing. The greatest growth (about 1.7 percent per year) is occurring in the industrial sector, followed by growth of approximately 1.1 percent in the commercial sector, and about 0.7 percent growth in the residential sector. The energy legislation in 1992 has the greatest impact on the growth rate of electricity use in the residential sector, somewhat less impact on the commercial sector, and relatively little impact on the industrial sector—hence, the growth rates that we see.

A question that brings us closer to the nuclear issue is, how do we expect the demand for electricity to be met in the future? Utilities have a number of options for meeting new demand. First, they can increase the utilization of existing plants. As you may be

aware, we have an excess of capacity in the nation today, by virtue of building capacity over and above what the actual requirements turned out to be in the 1970s and 1980s. Second, utilities also have the opportunity to prolong the lives of existing plants—perhaps by as much as another twenty years—as these plants reach their scheduled retirement dates. Third, there is the possibility of importing electricity from Canada and, to a lesser extent, from Mexico. Fourth, we might turn to nontraditional sources of supply, such as nonutility generators, the growth of which has been stimulated both by the Public Utilities Regulatory Policies Act of 1978 and subsequently by EPACT, which creates a whole new class of players called exempt wholesale generators. Fifth, in conjunction with the EPACT, we might opt to pursue more demand-side management, as part of an integrated resource planning process. And finally, the last option is simply to construct new plants. Let's review what each of these options provides in terms of sources of supply.

Utilization of plants is indeed expected to increase. We might look especially at the coal plants, which provide a substantial amount of baseload capacity. Their contribution is expected to increase in the future. We also have a significant contribution from combined-cycle plants, and from turbines fueled by natural gas; we will be increasing utilization of those in the future as well.

We also project that a substantial proportion of the existing stock of plants will have its life extended. To put this in context, we have about 700 gigawatts of capacity today in the United States. We are projecting that about half of that capacity will have some sort of investment made to prolong its life, ranging from modest investments that would improve performance above current levels to substantial investments that would bring plants up to their original design criteria in terms of performance. A substantial amount of coal-fired capacity, as well as oil and gas steam capacity, is expected to be rehabilitated one way or another. Of course, we also have to address the fact that a substantial amount of capacity will be retired in the next 15 years as well. Utilities report to us that approximately 15 gigawatts of capacity are expected to be retired over our forecast period. In addition to that, we have done an analysis that indicates that approximately 45 additional gigawatts will be retired, for a total of about 60 gigawatts of retired capacity between now and 2010.

This capacity will have to be replaced.

Another option available is imports of electricity from Canada and Mexico. Traditionally, net imports had been running at about 30 billion kilowatt hours prior to 1990. There were some problems in Canada in 1990, with the retrofitting of plants for emission controls and a bad hydro year, which caused net imports to plummet, but we expect to get back on track and to grow in the future. However, we expect this growth to be rather modest—up to approximately 40 billion kilowatt hours by 2010.

Nonutility sources of supply increasingly are expected to be players. In 1990, they represented about 8 percent of supply, and they are expected to grow significantly—to about 18 percent—by 2010. Utilities find nonutility sources desirable because they reduce the need for the utilities to make investments themselves, can be brought on line rather rapidly, and don't expose utilities to risk in terms of capital investments. If we look at the numbers, we expect the contribution of nonutility suppliers to more than double from 217 billion kilowatt hours in 1990 to almost 600 billion kilowatt hours in 2010; that represents a significant portion of the new generation requirements. We also expect a significant amount of energy savings to occur as a result of strategic demand side management (DSM) programs. We estimate that such programs may save up to 70 billion kilowatt hours in the next couple of years.

What happens, however, when we have exhausted all of these options, and we still cannot meet demand—which seems likely to be the case? We still have to build some capacity. Prior to the year 2000, we expect that short-lead-time, low-capital-cost items such as gas-fired turbines and combined-cycle plants will grow significantly. After 2000, we expect that the need for more baseload capacity will make the economics of coal more attractive, and as a result, we expect additional coal facilities to be built; gas and combined-cycle plants will also continue to be built, but at a lower rate than we had seen prior to the year 2000.

In terms of the nuclear contribution, we expect to see relatively modest increases in nuclear capacity after the year 2000. Our basic assumption with respect to nuclear capacity is that the existing stock of plants will operate for its 40-year operating life but will not have its life extended beyond that. Some plants will, of course, be retired prematurely, while others will have their lives extended; on balance, however, we expect to see

a 40-year operable life for the existing stock of plants. We have included a few plants currently under construction, but we have not included any facilities whose construction is not already planned at this point.

A significant amount of variation in projected capacity requirements occurs if assumptions are changed about economic growth. I mentioned that we have a low economic growth reference scenario and a high-growth scenario; if we consider the requirements for capacity and how they vary in response to economic growth, we see that there is a significant spread. Tiny variations in growth rates can have large absolute effects on these requirements. For example, if electricity growth rates deviate just 0.5 percentage points from what we expect—say, 1.5 percent growth instead of 1.0 percent—that translates into about 70 gigawatts of generating capacity.

Coal is and will continue to be the dominant fuel source for generating electricity in the United States, providing roughly 55 to 56 percent of generation. Nuclear capacity is expected to grow by a modest amount over the forecast period. The big winner is natural gas, which is being used in new combined-cycle plants and turbines. We expect a reduction in oil consumption for electricity generation purposes, but oil is not a major player in this area. We also expect to see increased penetration of nonhydrobased renewables, such as biomass, geothermal, wind, and, to a small extent, solar.

Let's now turn to what the specific nuclear contribution will be. If we look at the performance of nuclear plants historically, we see a sort of roller-coaster pattern. Following the incident at Three Mile Island, the contribution of nuclear generators to supply diminished because of the outages that were required for safety retrofits. Since 1989, when nuclear power plants were running at roughly 62 percent capacity, we have seen a marked increase in the utilization of nuclear capacity, to about 71 percent in 1992. We project a continuation of that trend, although at a much more modest rate. We project that nuclear plants will perform at about 74 percent capacity factor by the end of this century, and this will continue at this level through 2010.

One of the issues important to consider with respect to nuclear plants is the age of the plants and how long they will be available to meet demand. If you look at the population of plants today, a

substantial proportion are less than 20 years old. By 2010, we will have a different situation, in that much of our nuclear generating capacity will be well beyond its half lifetime, and by 2015, we expect to see a large amount of attrition in available capacity because of retirements. As a result, we see the post-2000 contribution of nuclear power to electricity generation declining. The nuclear contribution today is roughly 20 percent, and we expect this to decline to about 17 percent by 2010. Of course, this is dependent upon our assumptions of no premature retirements of existing plants and no construction of new facilities.

In terms of the requirements of the Clean Air Act Amendments of 1990, it is important to note that, although the coal contribution to electricity generation is expected to remain relatively stable in the future, the sources of supply of coal are expected to change. The consumption of high-sulfur coals is expected to decline by almost 100 million tons between 1990 and 2000 as utilities strive to comply with Clean Air Act Amendments of 1990 by switching from high-sulfur to medium- and low-sulfur coals. After the year 2000, because of construction of plants that meet the new source performance standard, there will not be as much of a decline in high-sulfur coal consumption; flue-gas-to-sulfurization equipment will allow facilities to burn higher sulfur coals and still comply with emissions standards.

It is interesting to note the impact of this level of coal consumption on the carbon emissions from electric utilities. These emissions amounted to about 480 million metric tons of carbon in 1990; our projections show this growing to about 520 million tons by 2000 and continuing to grow to almost 600 million tons by 2010. These forecasts do not, however, include any of the voluntary initiatives that may be undertaken by utilities to help meet the stabilization goals; these are simply the actual emissions that would occur as a result of the fuel consumption levels that we project in the absence of carbon stabilization programs.

I would like to briefly turn my attention to the question of the nuclear contribution to power generation in the rest of the world. As indicated, nuclear facilities supply about 20 percent of U.S. electricity today, whereas at the world level, we have a somewhat different situation. In Western Europe, almost two-fifths of supply are generated by nuclear plants, ranging to as high as 79 percent in France. On balance, the moredeveloped countries

of Western Europe and the United States have a substantial commitment to nuclear power; Japan is in the same category, with about 28 percent of its electricity generated in nuclear plants. Eurasia, which includes both China and the Eastern bloc countries, comes in at about 17 percent, with Eastern Europe at about 16 percent. The rest of the world pulls up the rear at about 10.5 percent. As in the United States, the nuclear contribution to electricity supply has been slowing in recent years, and we can expect it to continue to slow even further in the coming years.

I mentioned the age of reactors in the United States, and it is also important to note the age of reactors in the rest of the world. About 14 percent of worldwide capacity fits into the category of reactors that are mid-way in their life cycle, approximately 20 years of age. A substantial percentage of the capacity outside of the more-developed countries (particularly the United States and Britain) is quite young and will not face the same issues faced by the retirement and decommissioning isssues as soon as U.S. nuclear facilities will.

One of the main issues everywhere, of course, is at the back end of the fuel cycle: namely, how do you dispose of the nuclear waste. This has become a particular problem in the United States, Britain, and Europe. There are concerns about public safety. One of the initiatives that has been taken to address safety concerns is the formation of the Institute of Nuclear Power Operators in the United States, which considers safety and reliability questions; a counterpart organization formed in Europe called the World Association of Nuclear Operators, which is chartered to do much the same thing.

There are other issues that relate to the current situation in the world that are worth mentioning as well. First, the privatization initiatives in Great Britain demonstrated that private investors are not willing to assume the risks associated with nuclear plants. As a result, the ownership of these plants has remained under government control. Second, we are finding that, in terms of investment decisions that are being made in Europe, fossil-fuel-fired plants are considered a more attractive option than investments in nuclear plants, for which there does not seem to be much enthusiasm. Third, another confounding feature of the nuclear power situation in both the United States and the rest of the world is premature retirements. We have had a number of

plants that retired early in the United States, as has the St. Laurents reactor in France, a gas-cooled reactor only 21 years old; this raises concerns about the expected life of the rest of the stock of plants. We really do not have much empirical evidence that these plants will survive for 40 years, which is their assumed lifespan.

What can be done to improve the prospects for nuclear power? There are already a number of initiatives underway. There is the notion of standardizing designs, both in the United States and in Europe, as well as initiatives to speed up the licensing process. If we come to see the greenhouse warming issue as a serious issue that needs to be dealt with in a more radical fashion than has hitherto been the case, nuclear power may begin to look more attractive vis-a-vis fossil fuels—if issues of the economics of plant operation, public safety, storage of spent fuel, and financing can be resolved.

If we look to the future, we see that the nuclear contribution in the United States is expected to decline as we retire capacity. Approximately 14 gigawatts of U.S. capacity are expected to retire between now and 2010. The situation is similar in Western Europe, where seven countries will have less capacity in 2010 than they do today, despite projected growth in France's capacity of between 4 and 12 gigawatts. Japan has a rather aggressive nuclear power program that could result in anywhere from 12 to 23 gigawatts being built between now and 2010. Another leading player is South Korea, where we foresee an additional 5 to 9 gigawatts.

If we look at Eurasia, which includes China and the Eastern bloc countries, we have capacity growing by about 6 gigawatts, most of which would be occurring in China, the Czech Republic, Slovakia, and Romania. For the rest of the world, there is expected to be a significant amount of capacity built—something like 14 gigawatts, of which 6 gigawatts would be in Korea, 2 gigawatts in India, and about the same amount in Taiwan and Brazil. In particular, India, Taiwan, and Brazil, while still showing fairly modest levels of installed capacity, are in the midst of aggressive programs to build capacity.

On balance, then, the nuclear contribution is expected to show sluggish growth, increasing by about 10 gigawatts (from around 330 gigawatts worldwide) by 2010, about a 3 percent

increase. If we assume the resumption of orders elsewhere in the world, we might see up to an additional 70 gigawatts beyond that. On balance, we project a "go-slow" policy toward nuclear power, until the nuclear waste disposal problems and public concerns about the safety are resolved.

The Problem of Nuclear Energy Proliferation

Thomas B. Cochran

THE PROLIFERATION ISSUES RELATED to civil nuclear power have been recognized for almost two decades:

- Very small quantities of plutonium (Pu) and/or highly enriched uranium (HEU) are needed for a nuclear weapon
- It is very difficult to provide adequate security for separated plutonium and HEU at bulk-handling facilities (nuclear fuel reprocessing and fabrication facilities) where separated plutonium and HEU are found in nondiscrete forms
- Stockpiling of these materials in nonweapon states provides a dangerous breakout capability.

The security of fissile material in Russia, the need to dispose of large stocks of fissile materials from retired weapons, and the growing recognition that we must address the long-term proliferation risks associated with spent fuel once the protection afforded by the radioactive fission products has decayed away, represent new dimensions to these issues.

The amount of plutonium and/or highly enriched uranium needed for a nuclear weapon is very small. After almost a half century of living with nuclear weapons, considerable misinformation about the fissile material requirements for nuclear

---

Dr. Cochran is a Senior Scientist at the Natural Resources Defense Council (NRDC) and director of NRDC's Nuclear Program, where he initiated and directed participation in several joint U.S.-Soviet nuclear weapons verification projects. For his leadership in nuclear test ban verification, Dr. Cochran received the American Physical Society's Szilard Award (1987) and the Federation of American Scientists' Public Service Award (1987). Dr. Cochran is the author of numerous articles and working papers and has served as a consultant to numerous government and nongovernmental agencies on energy, nuclear nonproliferation and nuclear reactor matters.

weapons still exists. For single-stage pure fission weapons, a spherically symmetric implosion design requires the least amount of fissile material to achieve a given explosive yield, relative to other possible designs. For this kind of device the amount of fissile material required depends primarily upon the type of fissile material used (plutonium or HEU), the desired explosive yield of the device, and the degree to which the fissile material is compressed at the time disassembly of the fissile material begins due to the release of energy from the rapid nuclear chain reaction. The degree of compression achieved depends on the sophistication of the design and degree of symmetry achieved by the imploding shock wave. There are, of course, other factors , such as the timing of the initiation of the chain reaction and the type of neutron reflector used, but we will assume that the proliferant state or subnational group already has acquired the necessary skills so that these factors are of secondary importance.

Figures 1 and 2 show the explosive yield of a pure fission weapon as a function of the quantity of weapon-grade (WG) fissile material (WGPu in figure 1 and HEU in figure 2) for three degrees of compression. In the figures the degree of compression is labeled according to our judgment as to the sophistication of the design; that is, whether it represents low, medium or high technology. As seen in figure 1, the Nagasaki bomb, *Fat Man,* which produced a 20 kiloton (kt) explosion with 6.1 kilograms (kg) of WGPu, falls on the "low technology" curve. However, only three kilograms of WGPu compressed the same amount would still have produced a 1 kt explosion. A 1 kt yield is still a very damaging explosion with the potential to kill tens of thousands of people, depending on the population density and physical characteristics of the targeted area. Many tactical nuclear weapons that were in the U.S. nuclear arsenal had yields in the kiloton, and even sub-kiloton range.

But the bad news does not stop there. A nonnuclear weapons state today can take advantage of the wealth of nuclear weapons design information that has been made public over the past 50 years, and do even better. As seen in figure 1, to achieve an explosive yield of 1 kt, we estimate that from 1 to 3 kg of WGPu are required, depending upon the sophistication of the design. And from figure 2 we can estimate that some 2 to 7 kg of HEU are required to achieve an explosive energy release of 1 kt. Table 1

Figure 1. Yield vs. Pu mass (as a function of technical capability)

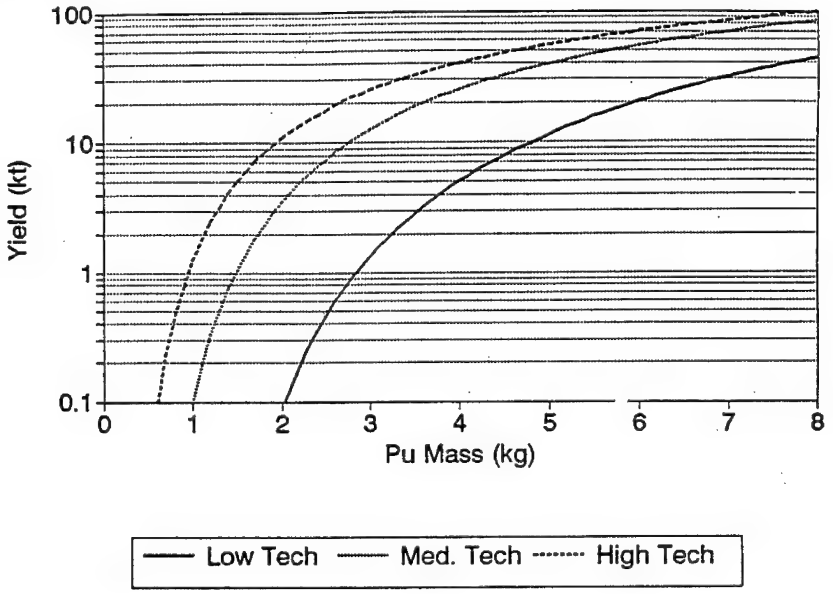


Figure 2. Yield vs. HEU mass (as a function of technical capability)

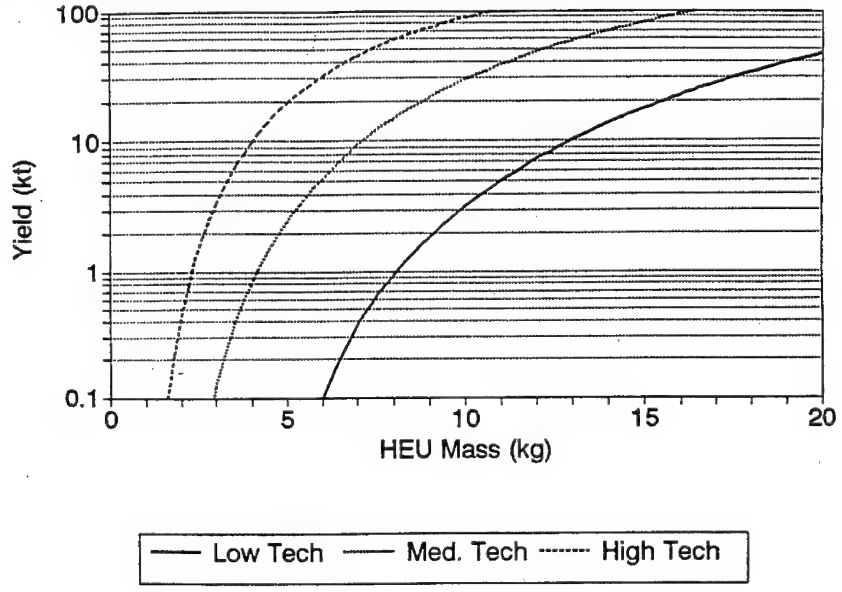


Table 1. Approximate fissile material requirements for pure fission nuclear weapons

	Weapon-grade Plutonium (kg)			**Highly enriched Uranium (kg)**		
Yield	*Technical Capability*			*Technical Capability*		
(kt)	Low	Med	High	Low	Med	High
1	3	1.5	1	8	4	2.5
5	4	2.5	1.5	11	6	3.5
10	5	3	2	13	7	4
20	6	3.5	3	16	9	5

presents some of the results of our calculations in a different form. We estimate, for example, that as little as 2 kilograms of plutonium, or about 4 kilograms of HEU, is required to produce a yield of 10 kilotons. The curves in figure 1 apply to weapon-grade plutonium where the Pu-240 content is less then 7 percent. Most of the plutonium in the civil world is reactor-grade with a Pu-240 content in the range of 20-35 percent. The critical mass of reactor-grade plutonium falls between that of weapon-grade plutonium and HEU.

Plutonium with a high Pu-240 content is less desirable for weapons purposes than weapon-grade plutonium, because for low-technology weapons designs the neutrons generated by the high rate of spontaneous fusion of Pu-240 can increase the statistical uncertainty of the yield by "preinitiating" the chain reaction before the desired compression of the plutonium core has been achieved. In spite of this, militarily useful weapons, with predictable yields in the kiloton range can be constructed based on low technology designs with reactor-grade plutonium. According to the conclusions of a recent study by the National Academy of Sciences in the United States, based in part on a classified 1994 study by scientists at the Lawrence Livermore National Laboratory,

> even if pre-initiation occurs at the worst possible moment (when the material becomes compressed enough to sustain a chain reaction), the explosive yield of even a relatively simple device similar to the Nagasaki

> bomb would be on the order of one or a few kilotons. This yield is referred to as the " yield " a one kiloton bomb would still have a destruction radius roughly one third that of the Hiroshima weapon; making it a potentially fearsome explosive. Regardless of how high the concentration of troublesome isotopes is, the yield would not be less. With a more sophisticated design, weapons could be built with reactor-grade plutonium that would be assured of having higher yields.[1]

By making use various combinations of advanced technologies, including improved implosion techniques, the use of beryllium as a neutron reflector, boosting with deuterium and tritium, and two stage weapon designs, it is possible to offset the problems created by the high rate of spontaneous fusion of Pu-240. Using sophisticated designs well within the capability of the declared weapon states, reliable light weight efficient weapons and high-yield weapons whose yields have small statistical uncertainties can be constructed with plutonium regardless of the Pu-240 content. NRC Commissioner Victor Gilinsky best summed up the issue in 1976:

> Of course, when reactor-grade plutonium is used there may be a penalty in performance that is considerable or insignificant, depending on the weapon design. But whatever we once might have thought, we now know that even simple designs, albeit with some uncertainty in yield, can serve as effective, highly powerful weapons - reliably in the kiloton range. [2]

Existing physical security measures provide insufficient insurance against theft of weapons-usable nuclear material. Adequate physical security is essential to prevent the theft of any quantity of materials even as little as one bomb's worth. Highly accurate material accounting and control measures are essential to determine whether a theft has taken place and provide timely warning to prevent the material from being used for illicit purposes. From experience at existing civil and military chemical separation (reprocessing) plants, naval fuel facilities, and mixed-oxide fuel facilities, it is well established that it is extremely difficult (some would argue impossible) to provide in practice a sufficient level of physical security and material accounting and control at bulk handling facilities that process large amounts of nuclear weapons-usable material.

The difficulty in providing adequate physical security is that theft of materials can involve a collusion of individuals, including

the head of the guard force, the head of the company, or even the state. Despite having guards at every bank, employees at the Bank of Credit and Commerce, Inc. (BCCI) were able to steal billions of dollars from bank customers because the thieves were running the bank—the collusion was at the top. If the threat includes the potential for collusion involving the guard force and facility directors, providing adequate physical security in the West would require turning the facility into a heavily armed site occupied by an independent military force. In Russia, physical security has relied on heavily guarding not only the facilities, but also the towns where the work force resides. These closed cities are anathema to a democratic society.

Of course, the principal role of physical security is completely reversed when the collusion involves elements of the government itself. In this case the primary mission of the security apparatus is to hide the program from outside scrutiny. It is now known that at various times in the past, the governments of the United States, Japan (during World War II, Soviet Union, United Kingdom, France, China, Israel, India, South Africa, Sweden, Argentina, Brazil, Taiwan, Pakistan, North Korea, South Korea, and Iraq have had secret nuclear weapons development programs.

The collapse of the Soviet Union and the current economic conditions in Russia have severely challenged the physical security of weapons-usable fissile material there. Russian President Boris Yeltsin has said that 40 percent of individual private businessmen and 60 percent of all Russian companies have been corrupted by organized crime. Reports of illegal activities in Russia associated with nuclear materials—offers to sell and successful and unsuccessful attempts to steal nuclear materials—are now appearing regularly in the Russian and European press. On average there is about one new case per week. Low-enriched uranium fuel has been stolen, and four tons of beryllium and a small quantity of HEU, thought to be less than 1 kilogram, was stolen from a Russian nuclear facility, perhaps Obninsk. These materials were recovered last year by Lithuanian authorities in Vilnius. This may be the case involving the theft of several hundred grams of HEU that has been confirmed by the Russian Ministry of Atomic Energy (Minatom).

In another case, a Russian nuclear scientist from the Luch Production Association, which manufactures nuclear space

reactors, was apprehended in October 1992 at the Podolsk train station with 1.5 kilograms of HEU in his suitcase. In February of this year 3 kilograms of HEU (90 percent U-235) were stolen from a plant near Moscow. Subsequently, a St. Petersburg butcher was apprehended in an attempt to sell it. Between May 10 and August 12 of this year German authorities intercepted four small samples of weapon-usable materials, one having 300 to 350 grams of plutonium. These are some of cases we know about because the materials were intercepted. We know for certain that kilogram quantities of weapons-usable materials are being stolen from Russian nuclear institutions and that some of it has crossed international borders. The most serious cases to date have involved weapons-usable materials in the civil sector. There may have been other diversions of nuclear weapons-usable materials that were successful and have gone undetected.

Plutonium-239 has a half-life of 24,000 years, and uranium-235 has a half-life of 700 million years. The lifetimes of weapon-usable materials greatly exceed the lifetimes of the institutions that must prevent their misuse. The situation in Russia today makes this abundantly clear.

IAEA safeguard measures are incapable of detecting diversion of weapons-usable fissile material from bulk handling facilities. The international community's principal tool for penetrating the secrecy of nuclear facilities is the power of the International Atomic Energy Agency (IAEA) to conduct inspections and require adherence to strict materials accounting and control procedures, collectively referred to as "safeguards." These are meant to provide timely detection of the diversion of significant quantities of weapons-usable material.

While there are numerous shortcomings in the design and implementation of IAEA safeguards, we focus here on three technical flaws: (a) the IAEA's "significant quantity"' (SQ) values are technically flawed—they are far too high; (b) detection of the diversion of a SQ amount applies to a material balance area, instead of the entire facility, or even country; and (c) the IAEA's timely detection criterion cannot be met.

For safeguards purposes the IAEA defines a "significant quantity" (SQ) of nuclear material as "the approximate quantity of nuclear material in respect of which, taking into account any conversion process involved, the possibility of manufacturing a

nuclear explosive device cannot be excluded."[3] Significant quantity values currently in use by the IAEA are given in table 2.[4] The SQ values were recommended to the IAEA by a group of experts, namely, the IAEA's Standing Advisory Group for Safeguards Implementation (SAGSI), and "relate to the potential acquisition of a first nuclear explosive by a non-nuclear weapon state."[5]

Table 2. IAEA significant quantities

Material	Quantity of Safeguards Significance	Safeguards Apply to:
Direct-use material		
Plutonium	8kg	Total element
Uranium-223	8 kg	Total isotope
Uranium enriched to 20 percent of more	25 kg	U-235 isotope
Indirect-use nuclear material		
Uranium ((20 percent U-235)	75 kg	U-235 isotope
Thorium	20 t	Total element

The direct-use values in table 2—that is, 8 kg of plutonium, 8 kg of uranium-233, and 25 kg of HEU—are also referred to by the IAEA as "threshold amounts," defined as "the approximate quantity of special fissionable material required for a single nuclear device."[6] The IAEA cites as a source for these threshold amounts a 1967 United Nations document:

> These threshold amounts include the material that will unavoidably be lost in manufacturing a nuclear explosive device. They should not be confused with the minimum critical mass needed for an explosive chain reaction, which is smaller. (IAEA footnote: Using highly sophisticated techniques available to NW states, the critical mass and the corresponding threshold amount can also be significantly reduced, but these are special cases that need not be considered here.)[7]

As seen from figures 1 and 2, the direct-use SQ or threshold values currently used by the IAEA are technically indefensible. The IAEA is making false claims as to the minimum quantity of nuclear material needed for a nuclear weapon, even for a low-technology first nuclear explosive by a nonnuclear weapon state, including consideration of unavoidable losses. If one took the same *Fat Man* design, first tested at the site in New Mexico and dropped on Nagasaki in 1945, and substituted a 3-kilogram plutonium core for the 6.1-kilogram core that was used in 1945, the yield of this device would be on the order of 1 kiloton, a very respectable atomic bomb. Thus, the IAEA is in error to assert that "highly sophisticated techniques available to NW States" are needed to make nuclear weapons with "significantly reduced" quantities of material.

The so-called "highly sophisticated techniques available to NW States" were known to U.S. weapons designers in the late 1940s and early 1950s, and nuclear devices using very small quantities of plutonium and HEU—so-called "fractional crit" weapons—with yields on the order of one kiloton were tested during the Ranger series in 1951. Furthermore, a well-advised safeguards program for a given country or group of countries would set the "significant quantity" levels at values less than the minimum amount needed for a weapon, in recognition of the fact that materials can be diverted from more than one source. The practice of setting higher levels to account for manufacturing losses is imprudent, particularly in view of the fact that a significant fraction of these "losses" are technically recoverable.

In sum, safeguards apply to all nonweapons countries, irrespective of their technological sophistication. Many countries, such as Japan, Germany, Israel, India and Pakistan, have highly developed nuclear infrastructures and must be considered technologically sophisticated. Even for countries that are in general not terribly sophisticated technologically, the key technical information needed to establish a program for achieving substantial compression by implosion techniques is now available in the unclassified literature. The quantities defining safeguards significance, therefore, must be based an the assumption that the proliferator has access to advanced technology. As a consequence, NRDC believes the IAEA's

significant quantities should be lowered at least 8-fold to the values in table 3.

Table 3. NRDC's proposed significant quantities

Material	Quantity of safeguards signifcance	Safequards apply to:
Direct-use nuclear material		
Plutonium	1 kg	Total Element
Uranium-233	1 kg	Total isotope
Uranium enriched to 20 percent or more	3 kg	U-235 Isotope

In the parlance of nuclear material accounting the inventory difference (ID) is defined as ID = BI + I - R - EI, where BI is the beginning inventory, EI is the ending inventory, and I and R are, respectively, the material added and removed during the inventory period.[8] For the minimum amount of diverted plutonium (assumed by the IAEA to be the SQ value (currently 8 kg of plutonium) to be distinguished from measurement noise with detection and false alarm probabilities of 95 percent and 5 percent, respectively, it can be shown that 3.3 σ_{ID} must be less than the SQ value, where σ_{ID} is the uncertainty in the inventory difference.[9] This means if the SQ value for plutonium were lowered to 1 kg, σ_{ID} should not exceed about 300 grams.

At reprocessing plants that handle tons of weapons-usable plutonium, σ_{ID} is dominated by the error in measuring the plutonium input into the plant, which is about one percent of the throughput. The Japanese Tokai Mura reprocessing plant, one of the smallest plants in the West, has an average output of about 90 t of heavy metal per year (the/t)), and the LWR spent fuel processed has an average total plutonium content of about 0.9 percent. Thus, σ_{ID} for Tokai Mura is about 8 kg of plutonium per annual inventory. Even if inventories were taken every 6 months, σ_{ID} would be about 4 kg, which is an order of magnitude too high. One simply cannot detect the diversion of several bombs' worth of plutonium annually from Tokai Mura. The inventory difference

would be larger at the plants in the United Kingdom and France because they have a greater throughput of plutonium.

We are told that material accounting and control at Russian plants handling nuclear fuel in bulk form is rudimentary at best. The RT-1 chemical separation plant at Chelyabinsk-65 has a capacity of about 400 the/y, and until 1991 had been operating at about 200 the/y. Therefore, the situation at RT-1 would be two to six times worse than at Tokai Mura, even if it were brought up to current Western standards.[10] It is difficult to imagine running a bank in which you counted the money only a few times a year, and then only counted the notes larger than 10,000 rubles. Yet the Russian nuclear establishment sanctions the commercial use of nuclear weapons-usable material under safeguards that are no better.

The IAEA permits facilities to reduce inventory uncertainties in two ways. First, the plutonium entering a reprocessing plant is not measured until after the spent fuel has been chopped up and dissolved, thereby sidestepping the large uncertainties in measurements of the amounts of plutonium entering the plant. Second, the facilities are subdivided into numerous material balance areas. The facilities in fact should be so subdivided, and this provides added protection against a single insider threat. But it must be recognized that this does not afford adequate protection against a collusion of individuals, particularly in scenarios where the state is engaging in the diversion.

In May 1994 the Nuclear Control Institute disclosed that there was a 70 kg discrepancy in the plutonium inventory balance at the Tokai Mura fuel fabrication plant The Japanese claimed the plutonium was not missing but was stuck to the surfaces of the glove boxes. Nevertheless, the uncertainty in the estimate of this plutonium holdup is on the order of 10-15 percent, one or more nuclear weapons worth. Astonishingly, the IAEA has given Japan months to resolve this discrepancy.

Detection time (the maximum time that should elapse between diversion and detection of a significant quantity) should be in the same range as the conversion time, defined as the time required to convert different forms of nuclear material into components of nuclear weapons. For metallic plutonium and HEU, the conversion time is 7 to 10 days; for other compounds of these materials, 1 to 3 weeks. These times are already much shorter than the period between inventories at any fuel reprocessing plant

operating today. Thus, there can be no assurance that the primary objective of safeguards—the timely detection of significant quantities of plutonium—is now being, or can be, met.

To meet the timely detection criteria, reprocessing plants would have to undergo clean-out inventories every few days, or weeks. But this would reduce their annual throughput—and utility—practically to zero. It would also drive up the cost of reprocessing. Plutonium recycle, the use of mixed-oxide (MOX) fuel in standard commercial LWRs, is already uneconomical because of the high costs of reprocessing and fuel fabrication even when conducted without a technically adequate level of safeguards. Similarly, the cost of the fast breeder reactor (FBR) fuel cycle is greater than that of the LWR operating on the once-through cycle without plutonium recycle.

In Western Europe and Japan, consideration is being given to Near-Real-Time Accountancy (NRTA) as a means of improving the sensitivity and timeliness of detection. NRTA involves taking inventories at frequent intervals, typically once a week, without shutting down the facility. It and similar concepts are likely to be opposed by operators because of the added costs that would be imposed. In any case the methods and adequacy of practical NRTA system implementation are open questions.

All nuclear weapons and weapons-usable materials should be places under some form of bilateral or international safeguards. Perhaps the greatest nonproliferation priority today is to improve the physical security and material accounting of warheads and weapons-usable materials in Russia. Russian nuclear weapons material naval fuel and civil reactor fuel facilities are highly integrated. Many of these facilities are old and cannot meet IAEA safeguard criteria. For these reasons, Russian officials are unwilling to consider IAEA safeguards over these facilities at this time. Consequently, the most promising means of achieving the necessary improvements is through U.S.-Russian and other bilateral efforts. To obtain full Russian participation, any bilateral effort must be on a completely reciprocal basis to avoid the appearance of meddling in Russia's national security affairs.

The most promising approach is through a cooperative program involving the nuclear weapons laboratories in the United States and Russia. The Department of Energy (DOE) launched such a cooperative lab-to-lab program in April of this year.

Unfortunately the mission of the DOE effort is too narrow. It is limited to improving the national physical security and material accounting programs in Russia. Unfortunately, the rate at which improvements will be made is funding limited: $2 millon in FY 1994, $15 million in FY 1995, and $40 million in FY 1996. Also, only a few facilities will be covered by the cooperative effort, and there will be little capability for the U.S. to observe the effectiveness of the U.S. assistance when applied to sensitive military facilities.

The mission of the lab-to-lab effort needs to be expanded to construct a comprehensive nondiscriminatory safeguards regime that covers all nuclear weapons and weapon-usable fissile material. Only then will the parties be forced to address methods for adequately safeguarding the most sensitive facilities and materials. There is no reason this should not be one of the mainline mission of the U.S. and Russian labs.

As seen from table 4, all the nuclear weapons and most of the fissile material facilities are not covered by the IAEA or even bilateral safeguards. As shown in table 5, even with the Clinton administration objectives of a global cutoff in the production of fissile material for weapons, and with IAEA safeguards placed over fissile materials declared "excess" to national security requirements, all nuclear warheads and many fissile material inventories and production facilities will remain outside any bilateral or international safeguards, including the weapons-usable material inventories in Russia. If we hope to achieve deep reductions in the global nuclear weapons arsenals, we will need a comprehensive safeguards regime covering all nuclear weapons and weapon-usable material (table 6). The U.S. and Russian nuclear weapons labs should begin constructing such a regime on a bilateral basis.

Proliferation risks associated with the closed fuel cycle. The United Kingdom, France, Russia, and Japan are reprocessing spent civil reactor fuel for waste management and to separate plutonium for recycle as a nuclear fuel in light water reactors and breeders. France, Russia, and Japan continue to develop plutonium breeder reactors. Not only is there no adequate means of safeguarding large bulk-handling facilities to prevent weapon-usable plutonium from being stolen, but also reprocessing of spent fuel and the recycling of plutonium[11] into fresh fuel for reactors permit nonnuclear weapons states to justify the

TABLE 4. CURRENT SAFEGUARDS

	WEAPON STATES		NON-WEAPON STATES
	DECLARED	UNDECLARED	
MILITARY:			
Warheads:			
Operational			
Reserve			
Retired			
Fissile Material:			
In Warheads			
Reserved for Warheads			
Declared Excess			
Facilities:			
Weapon Production			
Material Production			
Excess Material Storage			
NAVAL FUEL CYCLE:			
Facilities			
Fuel			
CIVIL NUCLEAR:			
Reactors		IAEA	IAEA
Fuel Cycle Facilities		IAEA	IAEA
HEU/Pu		IAEA	IAEA
LEU		IAEA	IAEA
Spent Fuel		IAEA	IAEA

TABLE 5. FISSILE CUTOFF FOR WEAPONS AND EXCESS STOCKS UNDER IAEA SAFEGUARDS

	WEAPON STATES		NON-WEAPON STATES
	DECLARED	UNDECLARED	
MILITARY:			
Warheads:			
Operational			
Reserve			
Retired			
Fissile Material:			
In Warheads			
Reserved for Warheads			
Declared Excess	IAEA		
Facilities:			
Weapon Production			
Material Production	IAEA	IAEA	
Excess Material Storage	IAEA		
NAVAL FUEL CYCLE:			
Facilities			
Fuel			
CIVIL NUCLEAR:			
Reactors		IAEA	IAEA
Fuel Cycle Facilities	IAEA	IAEA	IAEA
HEU/Pu	IAEA	IAEA	IAEA
LEU		IAEA	IAEA
Spent Fuel		IAEA	IAEA

TABLE 6. A COMPREHENSIVE SAFEGUARDS REGIME FOR THE 21ST CENTURY

	WEAPON STATES		NON-WEAPON STATES
	DECLARED	UNDECLARED	
MILITARY:			
Warheads:			
Operational	MONITORED		
Reserve	MONITORED		
Retired	MONITORED		
Fissile Material:			
In Warheads	MONITORED		
Reserved for Warheads	MONITORED		
Declared Excess	IAEA	IAEA	
Facilities:			
Weapon Production	MONITORED		
Material Production	IAEA	IAEA	
Excess Material Storage	IAEA		
NAVAL FUEL CYCLE:			
Facilities	MONITORED	MONITORED	MONITORED
Fuel	MONITORED	MONITORED	MONITORED
CIVIL NUCLEAR:			
Reactors	IAEA	IAEA	IAEA
Fuel Cycle Facilities	IAEA	IAEA	IAEA
HEU/Pu	IAEA	IAEA	IAEA
LEU	IAEA	IAEA	IAEA
Spent Fuel	IAEA	IAEA	IAEA

acquisition and stockpiling of nuclear weapons-usable material, ostensibly for peaceful purposes. At the same time, without violating any international safeguards agreements, these countries can design and fabricate nonnuclear weapon components. By moving to a point of being within hours of having nuclear weapons, perhaps needing only to introduce the fissile material into the weapons, a nascent weapons state would have all of its options open. Under these conditions, international safeguards agreements can serve as a cover by concealing the signs of critical change until it is too late for diplomacy to reverse a decision to "go nuclear." India recovered the plutonium for its first nuclear device in a reprocessing plant that was ostensibly developed as part of its national breeder program.

Acceptance of the plutonium breeder as an energy option provides the justification for the early development of a reprocessing capability by any country. A nonnuclear weapons country would always have the option to shift its "peaceful" nuclear program to a weapons program, but this would require the politically difficult decision to attempt evasion or overtly abrogate IAEA safeguards. Without national reprocessing facilities and breeder reactors, countries wishing to develop nuclear weapons capacity face very considerable political problems and cost. Obtaining large quantities of weapon-usable plutonium requires that they build one or more specialized production reactors and chemical separation facilities. By establishing their nuclear weapons option through a plutonium-using nuclear electric generation program, they can circumvent these obstacles.

Were plutonium fast breeder reactors ever to become economical (I seriously doubt this will happen), their deployment would entail staggering amounts of nuclear weapons-usable plutonium in the reactors and the supporting fuel cycle. [12] If only 10 gigawatts of electric capacity were supplied by breeders, hardly enough to justify the R&D effort in any country even if the economics were otherwise favorable, the plutonium inventory in the reactors and their supporting fuel cycle would be on the order of 100-200 t—sufficient for 17,000 to 33,000 nuclear weapons each using 6 kg of plutonium. By comparison, U.S. nuclear weapons stockpiles in 1987 consisted of 23,400 warheads, and the weapon-grade plutonium inventory, most of which was in

weapons, was about 90 t. The Russian warhead plutonium stockpile consists of an estimated 135-170 t of plutonium in a total stockpile which peaked in 1985 at about 45,000 warheads.

Moreover, about one-half of the plutonium created in a breeder reactor is bred in the blanket rods. The burnup of the blanket material is low. Consequently, the resulting plutonium is weapon-grade, with a Pu-240 concentration lower than that used in U.S. and Russian weapons. Thus, any nonweapons country that has large stocks of breeder fuel has the capacity to produce a ready stock of weapon-grade plutonium. It only has to segregate and reprocess the blanket assemblies separately from the core assemblies.

Consequently, remaining breeder research and development programs, if not deferred altogether, should be limited to conceptual design efforts only, with an emphasis on advanced proliferation resistant fuel cycles that do not require mastery of the technology for isolating and fabricating weapons-usable nuclear materials. To the extent that this is politically impossible, sufficient plutonium has already been separated to meet the needs of R&D programs, so at a minimum there is no requirement to continue separating plutonium for this purpose. In this connection it should be noted if plutonium breeders some day prove to be economically competitive, and if the breeder fuel cycle can be safeguarded with high confidence under stringent international controls, then commercial deployment could begin with cores of nonweapons usable 20 percent enriched uranium. *In other words, there is no need to accumulate a stockpile of separated plutonium today to insure the possibility of deploying breeders at some point in the future.*

Civil Plutonium Stockpiles are a potential barrier to achieving deep reductions in the global nuclear arsenals. The accumulation of large stockpiles of separated plutonium and weapon-usable expertise in nominally civil programs will act as a barrier to deep reductions and eventual elimination of nuclear weapons held by declared and undeclared weapon states. One need only ask how far China, for example, might be willing to go in accepting limits on, or reductions in its nuclear weapons stockpile if Japan is poised to accumulate an even larger inventory of weapons-usable fissile materials in pursuit of a civil plutonium program with no clear commercial rationale. Similarly, Russia's continued operation of

reprocessing plants and potentially large-scale commitment to the breeder reactor fuel cycle could abort U.S. political support for continuing toward very deep reductions and ultimate abolition of nuclear weapons stockpiles. The lack of such a commitment by the United States and other nuclear weapons states could, in turn, lead to continued erosion of the nonproliferation regime. Hence the need to forthrightly address the mistaken legitimacy afforded civil plutonium programs under the current system of international controls. In any case, nations having civil nuclear energy programs with closed fuel cycles can make an important contribution to the disarmament process by deferring further separation of plutonium until the global inventories of plutonium are substantially reduced.

Plutonium economics. Development efforts worldwide have demonstrated that plutonium fast breeders are uneconomical—unable to compete with thermal reactors operating on a once through uranium cycle—and that breeders will remain uneconomical for the foreseeable future. The putative benefits of the plutonium breeder, associated with its ability to more efficiently utilize uranium resources, are not diminished if commercial breeder development is postponed for decades, and the spent fuel from existing conventional reactors is stored in the interim. As thoroughly documented by Paul Leventhal and Steve Dolley of the Nuclear Control Institute, energy security in the nuclear sector can be achieved more cheaply and more quickly by stockpiling uranium.

The use of plutonium in the form of MOX fuel in conventional power ("thermal") reactors is likewise uneconomical because the costs of using MOX fuel cannot compete with those of enriched fresh uranium fuel for the foreseeable future. A recent study by the RAND Corp. estimates that, at the current cost for reprocessing services, the price of uranium feedstock for enrichment would have to increase by a factor of 16 before plutonium recycle in LWRs becomes competitive.

At current reprocessing costs and an FBR/LWR capital cost ratio of 1.5, the yellowcake price would have to increase by a factor of 45 before the breeder becomes competitive. When might this happen? The earliest date, based on the most optimistic assumptions about nuclear energy growth, reprocessing costs, and breeder capital costs, is at least 50 years away, and the more likely case is 100 years away. On the timescale for technology

development, a period of 50 to 100 years is a very long time, during which more efficient fission options may emerge, to say nothing of advanced solar and new energy technologies not yet invented.

Accumulating a plutonium inventory today is not required to insure a sufficient startup fuel supply for breeders. If the time ever comes when plutonium breeders are both economically competitive and proliferation resistant, startup cores can be made from reserves of uranium enriched to about 20 percent U-235 (Because the critical mass of 20 percent enriched uranium metal is 14 times that of 93.5 percent enriched HEU metal, it would require on the order of 35 times or more, 20%-enriched HEU compared with the amount of weapon-grade plutonium needed, and the same increase in the amount of high explosive, to achieve a comparable yield). *Consequently, there is no sound economic or energy security justification for continued commercial reprocessing.*

Despite these realities, however, by the end of 1990, France, the United Kingdom and Japan alone had separated about 90 t of civil plutonium, and these countries plan to separate an additional 170 t by 2000. The global inventory of separated civil plutonium (i.e., not fabricated into fuel or in use in reactors) will rise to an estimated 170 t by the turn of the century—that is, almost two times the size of the U.S. weapons plutonium stockpile at its peak. This amount would be in addition to more than 100 t of plutonium likely to be removed from retired U.S. and former Soviet weapons.

Conclusion. At the dawn of the nuclear age, the authors of the famous Acheson-Lilienthal plan for international control of atomic energy clearly recognized the inherent military potential of fissile materials used for ostensibly peaceful purposes. Indeed, they believed that no widespread use of nuclear energy for civil purposes was possible or desirable without international ownership and control of the full nuclear fuel cycle.

Today it remains the unanimous opinion of the weapons design and arms control communities that the pacing consideration in a country's acquisition of a nuclear weapon is not the capability to design a nuclear device, but the availability of fissile materials that can be turned to weapons purposes. Ending, as opposed to managing, nuclear weapons proliferation will likely

prove impossible as long as production of HEU and chemical separation of plutonium for national security needs remain legitimate activities in a particular class of "nuclear weapon states." The international control regime permits civil nuclear fuel reprocessing in any state that asserts a peaceful interest in plutonium recycle and future deployment of plutonium breeder reactors for energy production.

With the end of the Cold War, and the reductions in the superpower arsenals, the United States and Russia have huge surpluses of weapon-grade plutonium and highly enriched uranium. Undoubtedly, there is no need for additional weapons plutonium production in other declared weapons states. *By completely renouncing the production, separation, and isotopic enrichment of weapons-usable nuclear materials, declared weapons states can put pressure on undeclared weapons states to do the same.* Weapon-usable fissile materials have no legitimate application in today's energy marketplace and can always be produced in the future should the appropriate market and international security conditions emerge.

Despite the fact that all types of plutonium in relatively small quantities, irrespective of their designation as civil or military, have an inherent capability to be used in weapons, the current nonproliferation regime allows national separation and acquisition of plutonium (and highly enriched uranium) under an internationally monitored commitment of peaceful use. A more effective nonproliferation approach would be a global ban on the production, transfer, acquisition, or isotopic enrichment of separated plutonium and on the isotopic enrichment of uranium to greater than 20 percent U-235.

The heavy commitment of United Kingdom, France, Japan and Russia to spent fuel reprocessing and recycle of plutonium and the lingering hopes of a future revival of the plutonium fast-breeder programs have effectively barred consideration of such a direct step as outlawing production and acquisition of weapons-usable fissile materials globally. While there are obvious technical advantages in such a comprehensive approach, tangible political progress will more likely be achievedby adopting parallel approaches that seek separate controls (in the initial stages at least) on the military and civil applications of weapon-usable fissile materials.

Notes

1. *Management and Disposition of Excess Weapons Plutonium, Committee on National Security and Arms Control,* National Academy of Sciences, Washington, DC 1994, (prepublication copy) 37.

2. Victor Gilinsky, Plutonium, Proliferation and Policy, Commissioner, Nuclear Regulatory Commission, Remarks given at Massachusetts Institute of Technology, November 1, 1976 (Press Release No. S-14-76).

3. *IAEA Safeguards Glossary, 1987 Edition,* IAEA/sg/inf/1 (REV. 1), 1987, P 23.

4. Ibid., 24.

5. Thomas Shea, "On the Application of IAEA Safeguards to Plutonium and Highly Enriched Uranium from Military Inventories," IAEA (June 1992, with additions December 1992).

6. Ibid., 23.

7. *Effects of the Possible Use of Nuclear Weapons,* United Nations, 6 October 1967.

8. In the literature, "inventory difference" is sometimes called "material unaccounted for," or MUF.

9. Marvin Miller, "Are Safeguards at Bulk-Handling Facilities Effective?" Nuclear Control Institute, Washington DC, August 1990.

10. According to Evgeni Dzekun, chief engineer of the Mayak civil reprocessing plant at Chelyabinsk-65, a plutonium input-output balance for the plant is calculated every 3.4 months when the plant is cleaned out between reprocessing campaigns. About one percent of the plutonium is lost to waste streams, and a lesser amount to plateout in the plant's plumbing. The ID is typically 15 kilograms of Pu per campaign, amounting to a total ID of about 3% percent of throughpt In other words, the ID is almost twice the IAEA's significant quantity for plutonium. According to Dzekun, if the ID in a given campaign is larger than can be explained by measurement errors, a 'special investigation' is carried out, but what this consists of is not known. To assure detection of an 8 kg. diversion at this plant with 95 percent confidence and a 5 percent false alarm rate, 3.3 x ID must be less than 8 kg, so this plant apparently falls short of the minimum IAEA standard by a factor of six. If 4 kilograms is regarded as the amount needed for a weapon, then the 'safeguards' at Mayak need to be improved by a factor of twelve in order to provide confident detection of diverted material See "Report on an International Workshop on the Future of Reprocessing, and Arrangements for the Storage and Disposition of Already Separated Plutonium" (Moscow, 14-16 December 1992) by F. v .Hippel, Princeton University, and T.B. Cochran, C. E. Paine, Natural Resources Defense Council, 10 January 1993, 5.

11. Or any other weapons material, such as HEU or Uranium-233.

12. With a plutonium breeder economy the quantity of plutonium involved would be enormous. The plutonium inventory in a commercial-size breeder is about 5 t, of which 3.5 t is fissile—sufficient for 800 atomic bombs using 6 kg Pu each. A Russian BN-800 breeder would require over 4 t. Although the net amount of plutonium produced in a fast breeder reactor annually is generally less than that produced in a conventional thermal power reactor of the same size, one-third to one-half of the FBR fuel must be removed annually for reprocessing, plutonium recovery, and remanufacture into fresh fuel. Since the fuel will be outside of the reactor for 3.5 to 7 years the plutonium inventory to support a single plutonium breeder is 11-22 t—sufficient for 1,800 to 3,600 atom bombs using 6 kg Pu each.

Discussion: Nuclear Issues

Question: What is the reason for the breakdown of the relationship that prevailed in the past, in which growth in electricity use led rather than lagged GDP growth?

Robert Eynon: The relationship between GDP growth and electricity use has been heavily affected by the efficiency and conservation initiatives that have arisen in response to the higher energy prices that resulted from the energy shocks of the 1970s. We have what is called "naturally occurring conservation," which has caused the growth in electricity sales to be smaller than would have otherwise been the case. Further, some saturation has occurred—for example, we now have substantial saturation of air conditioning in the United States; how much more can you air condition? Of course, that is balanced off against some of the novel uses of electricity that were not anticipated—for example, use of electricity for PCs and fax machines was not included in projections on electricity requirements until quite recently. On balance, however, I think that conservation and saturation explain the new relationship between electricity and GDP growth, and what you see in this country is fairly typical of what you see in the rest of the world, particularly in the highly developed countries. I might also add that, while significant energy efficiency gains have occurred, we still believe that further major gains are possible. For example, some of the strategic demand-side management programs at the utilities focus on efficiency gains that are still out there, waiting to be exploited.

Question: First, could disagreements over the terms of nuclear technology transfer scuttle the prospects for an extension of the Nuclear Nonproliferation treaty? And second, are any new countries likely to develop indigenous nuclear energy capabilities in the foreseeable future?

Tom Cochran: I would say that the countries that have the technological capability to build their own nuclear energy programs have already done so. The possession of nuclear

capabilities by states such as North Korea and Iran is, of course, a cause for concern, but such states generally get assistance from other states that have advanced programs. I don't see many, if any, more countries getting into the civil side of the nuclear power business by doing it on their own. Concerning your first question, I don't think the issue of technology transfer under the NPT is going to be an important issue in the review conference. To be sure, some words will be thrown around, but this issue does not have the potential to derail the extension of the NPT. In terms of voting, the United States and other countries have counted the votes, and they have enough to extend the treaty; they would like more support, but they do have the votes to pass it. They will probably separate out the issue of voting to extend the NPT from other issues, such as technology transfer and assistance.

Question: Please comment on the safety issues surrounding Soviet-era nuclear reactors in the former USSR and elsewhere.

Tom Cochran: I have not spent a lot of time studying the reactor safety issue in either Russia or the Eastern European countries that have reactors of Russian design. However, it is obvious that there are horrendous safety problems with all of the Russian reactor designs, particularly the RBMK designs. The Russians are not going to build any more of these; the question is whether the nations in which such reactors are in service will be able to shut them down any time soon. This is a particular problem in Ukraine, where there are internal fights about how long to continue operating the balance of the Chernobyl plants. One aspect of this that I would hope the Department of Energy would look at concerns the VVER-440 reactors—pressurized water reactors of Russian design that are operating in Finland, Ukraine, and Eastern Europe. Their spent fuel has been returned to Russia for reprocessing, and this operation now represents a source of hard currency for the only reprocessing plant in Russia that deals with civil reactor fuel—the other two reprocessing facilities are solely for processing spent fuel from Russia's three remaining military reactors. I think the United States should assist Eastern European countries in spent fuel management regimes that avoid reprocessing; this would deprive that reprocessing plant of the tens of millions of dollars that keep it in operation.

V. U.S. Energy Vulnerability

Macroeconomic Consequences Of Oil Supply Shocks

Hill G. Huntington

I WILL ADDRESS THE THREE MAIN QUESTIONS posed by this conference from the standpoint of an economist:

- What constitutes an energy shock? Specifically, how big would a disruption have to be in order to generate concern?
- What is the likelihood of such an event?
- What are the economic consequences of an event like this?

This may not have much to do with modeling, but I hope it will be a whole lot more interesting.

First, how big would an oil supply shock have to be before it was something we would want to worry about? Unfortunately, it is impossible to be precise in answering such a question, and formal modeling is only modestly useful. A small disruption might have serious economic consequences if certain conditions prevail. However, it is important to reemphasize a point that has

---

Dr. Huntington is the Executive Director of the Energy Modeling Forum (EMF), Stanford University, where he conducts studies to improve the use and usefulness of energy models for business planning and policy analysis. Prior to coming to Stanford in 1980, he was the Director of the Washington Energy Office for Data Resources, Inc.

already been made by several speakers today: when world oil markets are basically free to operate, the economic consequences of an oil disruption flow from the price shock that it generates, not from a tangible shortage of oil supplies. A lot of factors affect how the economy will react to such a disruption. The first of these is the availability of offsetting supplies—for example, Saudi productive capacity and the willingness of the Saudis to increase output or, as happened in the 1970s, to curtail it. Second, the response of supply and demand to price shifts is another major factor that determines the effects of a price shock. The less responsive both of these are to price, the larger the required adjustments. And finally, no discussion would be complete without bringing in the important role played by expectations; if you go back to the 1979-80 shock, for example, you see the consumers rushed to augment their inventories, because they expected the shortfall to get worse. So all these things have to be brought in, and it becomes very difficult to put a precise figure on the number of barrels of oil that would have to be removed for us to get concerned.

Many economists are very optimistic about how well the markets can adjust to supply disruptions, for several reasons. One is that the regulations and price controls that encumbered oil markets in the past have now been largely eliminated, enabling market signals to move much more quickly, and to more accurately reflect the information we need to make sound decisions in such circumstances. Also, we now have the futures markets for diversifying risks; many people feel that these mechanisms will reduce the negative effects of a supply shock. However, at some point, people will start to ask the question, how well and how quickly will markets work? And if they don't work quickly enough, will politicians step in with price controls or other such measures?

After considering all these issues, we at the Energy Modeling Forum decided that, for our the series of workshops on the causes and effects of supply disruptions that I will describe shortly, we would focus on sudden shortfalls of at least three million barrels per day, for 6 months or more. Clearly, this is not an exact science, but that is the number we came up with after weighing what we considered to be the relevant factors. This meant that we were essentially confining our attention to a disruption in oil supplies from the Persian Gulf region. That is not to say that you might not get

other types of situations, of course, but that is just where we decided to focus our thinking.

The second question is, how likely is such a supply shock? The discussions this morning by both Congressman Sharp and Dr. Kanovsky did a nice job of setting out what appear to be the concerns in Saudi Arabia, so I am not going to go over that territory again. Instead, I will talk about how we might *think* about this question, and this is where we might use a little bit of formal modeling. In this case, we are talking about modeling in the sense of considering the situation in a structured and systematic way; this is not the kind of energy modeling that people are used to thinking about, but we have found it helps our thinking on these issues immensely. Thus, what I am about to describe is primarily a *process* that is currently underway at the Energy Modeling Forum, and this process has not continued long enough to yield any definite answers at this point.

In our group is a set of workshops to develop a risk assessment framework—that is, a means of trying to quantify the risk of disruption, based upon expert opinions on key uncertainties. As those of you who work on energy security policy analysis know, a critical factor is the *probability* of a disruption, and often this probability is just assigned a number—we think about a range of possible events, and then come up with a number based on our analysis. Our motivation in this effort has been to decompose this probability into certain well-defined components and events. For example, we might look at the situation in Saudi Arabia, considering in detail the sorts of events that might lead to supply disruptions there both in terms of the likely consequences of such events, and of the probability that these events might actually occur. Then we hope to fold all that analysis up into some kind of overall assessment about the likelihood of a disruption of a particular size. In the process, this kind of approach does two things. First, it helps the experts to think more carefully about a wide range of political events and market adjustments, thus making sure that they bring the full extent of their expertise to bear on all possibilities. And second, it stimulates dialogue among the experts concerning the areas in which they disagree.

This approach begins with a very detailed picture that tries to capture all of the different events that could lead to a disruption and tries to identify the key influences that dominate the situation. From that, we hope to derive a simplified structure that will enable

us to construct some sort of risk analysis model and thus to come up with some sort of number that represents the probability of a shortfall of a given magnitude, expressed as a percentage of world consumption.

We are trying to bring in a wide range of experts from business, government, and academia. We are in the process of contacting experts to participate in the assessment at the moment, and it will be several months before we actually get any sort of numbers here.

That's all I want to say about the probability of a disruption. Based on what we heard this morning, and what I have learned from other sources and from our own assessments, there seems to be a good possibility that some sort of supply disruption will eventually occur. I think you have several scenarios today that might create some cause for concern, and I will just leave it at that.

That leads me to the third question: what would be the economic consequences of a disruption? Again, I want to re emphasize that we are talking about the consequences that flow from higher prices, not from a physical loss of supply. Economists have distinguished between direct and indirect effects of a such a disruption. I should mention at the outset that I will be talking about these things as losses, but there is disagreement among economists about what really does constitute a loss, n particular, a reduction in GNP does not always mean an economic loss. That's an issue I do not what to get too deeply involved in, but I do want to add that caveat.

I prefer to think about direct losses simply as a loss in purchasing power, even if nothing happens to economic output. For example, even if nothing changes in terms of economic output, you might still have a loss of purchasing power because the price of oil is rising faster than the prices of the goods that a nation produces, and therefore that nation must produce more domestic goods and services for export to pay for each barrel of imported oil. Another way of looking at it would be to say that domestic wages do not change, but the prices of the goods and services that you are buying increase. You can link these direct losses to the level of oil imports at the time of the disruption, so in that sense, the level of oil imports could be directly tied to the magnitude of effects that arise as the result of a disruption.

I happen to think that these direct effects are not a major factor, and many analysts agree with me, although we should note that oil imports are increasing according to most projections and therefore this mechanism could turn out to be more important in the future than we think it is now. But I still tend to believe that the level of imports may not be as important as the public seems, at least in terms of the effect of imports on energy vulnerability and economic losses. Rather, I tend to think that the more important effects arise from what economists call the indirect losses.

There are many different suggestions for how these indirect losses occur. I subscribe to the view found in a typical macroeconomic textbook that says because they are not offset by lower prices elsewhere in the economy, higher oil prices will be translated into the wage system, leading to upward pressure on the price level and reduced aggregate spending. If other prices in the economy were to fall when oil prices rose, you wouldn't have this problem. But they don't fall; there is this rigidity or "stickiness" in a downward direction, and that makes it more difficult for the economy to adjust. In a sense, indirect losses to a given sector of the economy have nothing to do with the question of whether that sector is energy-intensive or not; rather, it has more to do with how investment-oriented a particular sector is, because the investment part of the economy gets hurt quite a bit in this process. These losses in output and employment from an oil price shock are basically temporary in nature, and eventually the economy recovers. But in the meantime, we go through this painful transition period, which gives politicians a good excuse to step in and "do something."

Our discussions this morning implicitly assumed that there would be some serious macroeconomic effects from an oil supply disruption. However, there is a debate within the field of energy economics about whether or not it is the price shocks themselves that cause these effects, or the bad economic policy that these shocks often call forth. I would be remiss not to at least briefly sketch that debate. Given the time constraints, I am not going to be able to argue the case for either side in much detail, although I tend to favor the side that says the disruptions themselves cause real effects, at least for the U.S. economy.

A lot of this work got started because many people were looking at how macroeconomic models applied to the case of

energy supply shocks. We did a study a while ago that analyzed the macroeconomic models, which were showing a fairly large impact from an oil price shock. More interestingly, some statistical studies have been done recently on aggregate U.S. economic activity. These models do not attempt to impose any particular economic logic on their subject—they're not Keynesian, monetarist, supply-side, or whatever, but they aim just to let the data tell the story. About three or four of them are out now, and I believe the most recent one has carried the analysis out through 1991 or 1992. These studies suggest that oil shocks tend to be followed by fairly serious declines in overall output, even adjusting for changes in macroeconomic policy.

For example, a study by Knut Anton Mork indicates that GNP falls with rises in oil prices, and a doubling in oil prices would cause something like a 5 percent loss in GNP after about six quarters. (Incidentally, these numbers are identical to the projections that we made 10 years ago in the Energy Modeling Forum. This is actually somewhat embarrassing for me, because I have been telling people lately that I think the numbers have changed for various reasons, and I go through these very careful arguments about why I think this is the case. Then this guy comes up with the same estimate I had before, using a totally different approach.) It has often been said that such estimates don't take policy into account so Mork threw in the key policy variables—control of the money supply, taxes, and so on—and he found basically the same response.

It is not just Mork's study that tells this story; there are now a number of studies that have demonstrated similar effects on the U.S. economy at the aggregate level. So it seems that one set of studies is saying that the economic effects of an oil price shock tend to be fairly large, even after doing the best that we can to control for policy variables. Some people have interpreted this to mean that the link with policy is just not there.

Interestingly enough, these studies also show that *reductions* in oil prices do not stimulate economic activity. This would seem to fit well with the explanation of macroeconomic adjustment that I prefer, which depends critically on an asymmetry in the way that prices behave—namely, they don't go downward, but they can go upward.

Many energy economists prefer to ignore these studies. First, the overwhelming majority of economists are trained as

microeconomists, and these results don't fit well with microeconomists' preconceived notions about how relative price increases in a relatively small sector can hurt the much larger aggregate economy. Second, the correspondence between oil prices and the economy suggested by these models would weaken the argument for government intervention in energy policy, which most energy economists tend to favor.

So that's one set of evidence. But there are other empirical studies that support the view that policy is what really counts, and that the price shocks themselves do not seem to have such a dramatic effect. One is a study that Doug Bohi did for Resources for the Future, which concentrated on industry-by-industry behavior in four OECD countries and showed that energy intensive sectors were not disproportionately hurt by the change in relative prices resulting from the price shock. However, this finding need not be inconsistent with the studies mentioned above. If oil shocks cause economywide adjustments that affect wages and investment, one would not necessarily expect energy-intensive sectors to be more severely affected than others. Further, I would suggest that this result needs to be duplicated with other data.

So this is a thumbnail sketch of why I think that oil price shocks do, in themselves, produce fairly serious effects. And now we have to ask the following sort of question: even if an oil supply shock can cause effects, why can't we just use policy to offset these effects? I think that the problem there is that monetary and fiscal policies are not designed to cushion the impact of supply shocks that really affect our productive capacity, as opposed to demand-side problems. At least in the U.S. economy, demand-side policies like expanding the money supply only contribute to the inflationary pressure that oil shocks ignite. So the traditional policies that the government uses for these sorts of situations are not very useful in the case of oil shocks. Then the question becomes, what *can* we do? By default, we seem to be in the position of relying upon stockpiles, which we would could release to help dampen the price shock before its effects take hold. Certainly, it would be nice to be able to do something other than simply letting the politicians say, "Well, we have to do *something*, so let's jump in with some price controls." This is the fear that Congressman Sharp expressed, and one that I share.

Economic losses are tied to price shocks, not physical shortfalls. I suggest that we look at scenarios that deal mainly with the

Persian Gulf and that would entail a sudden loss of about three million barrels per day or more; however, there is nothing magic about that number—it's just a judgment call. I share the skepticism that has been shown here concerning the popular myths about oil imports: if you are talking about energy vulnerability and energy security issues, reducing oil imports at the margins does not make us all that much more secure. I won't belabor that, because it has already been said. Finally, I do part ways with a growing number of my energy economist colleagues in that I think we have underestimated the macroeconomic problems associated with oil supply shocks.

The Ghost of OPEC

Vito Stagliano

ENERGY SECURITY ENTERED THE LEXICON of American public policy in the wake of the Arab oil embargo of 1973. Rooted in the conflict of the Middle East, and linked to the vast petroleum supplies of the Persian Gulf, security considerations have dominated U.S. energy policy thinking for two decades. The security dimensions of energy policy have profoundly complicated the otherwise technical and economic debate about the transformation, transportation, trade, and use of energy and have moved energy policy from the administrative to the political, and therefore unstable, center of Federal decisionmaking.

As a policy objective, energy security has proved elusive. For two decades Federal and State governments have experimented with a wide range of regulatory, taxation, and research policies in a futile effort to reverse a political and geologic reality: the Persian Gulf s oil wealth and political instability. The evidence now seems conclusive that the chronic instability of the world's most prolific oil-producing region is unlikely to be resolved by means of a U.S. energy policy. But oil could be traded in a freer market to the benefit of producers and consumers alike . The Organization of Petroleum Exporting Countries (OPEC) represents one of the few remaining cartels in a generally unencumbered global trading system. Its dissolution would eliminate the potential as well as the perception of governments in collusion, and could prove liberating to its cantakerous members. The OPEC nations would achieve fuller integration into the global economy by earning competitive status. Western governments, for their part, would

---

Vito Stagliano is a visiting fellow at Resources for the Future. Previously he was the Deputy Assistant Secretary for Policy Planning at the Department of Energy. He is the author of *A Policy of Discontent: The Making of the National Energy Strategy* and has lectured at Harvard's Kennedy School of Government, the Fletcher School of Law and Diplomacy, the National Defense University, the Virginia Military Institute, and the Ecole Nationale Superieure in Paris.

abandon the remnants of protectionism and shed the costly illusion of security.

Background

President Nixon institutionalized the view of energy as a defining element of national security by characterizing the oil market events of 1973-1974 as a "blow to American pride and prosperity; a turning point in our history." He gave legitimacy to the misleading but politically expedient view that discrete and temporary disruptions of the oil market could be considered to infringe on the national sovereignty. He clad energy security in presidential prestige, as an issue critical to the success and failure of administrations, and presided over the most significant expansion of Federal involvement in the energy sector since the New Deal. He set the pattern as well for obsessive Federal behavior on energy policy, a practice that would later consume another presidency. He also embodied the tendency of government to overreact to temporary crises; Nixon's response to the oil embargo of 1973 included the proposal to employ what he referred to as small nuclear devices to stimulate production of methane gas from tight sands formations.[1]

The energy crisis highlighted the role of politics in policy. Congress showed reluctance to take demonstrably effective but unpopular steps such as deregulation of the oil sector, but was easily persuaded to appropriate funds for programs and projects of dubious public policy value. Federal spending as a substitute for policy reform remained popular for most of the 1970s. It fit the high-cost / high-pork national defense model and satisfied a diverse and vocal special interest community that believed the power of policy was proportional to public expenditures. President Ford easily absorbed the terminology and instruments of energy security policy. He told the nation in 1975 that "Americans are no longer in full control of their own national destiny, when that destiny depends on uncertain foreign fuel at high prices fixed by others." He proposed a sweeping federal investment program to produce fuels from exclusively domestic sources; to build pipelines, power plants, production facilities and even new railroads and ports; and to suspend environmental regulations which might impinge upon these efforts. As an afterthought, he added to his

Project Independence a meek regime of oil and gas prices deregulation.

President Carter, for his part, devoted the better part of his 4 years in office to the energy crisis of 1979, alternately cajoling and hectoring Americans to enter "the battlefield of energy to win for our Nation a new confidence, and to seize control again of our common destiny." His battle plan comprised a surprisingly more aggressive energy price deregulation policy than advocated by his Republican predecessors, but also more extensive government control of energy end-use sectors, prohibitions against the use of natural gas in electricity generation, preprinting of gasoline rationing coupons in expectation of the next oil crisis, and the ill-fated $75 billion Synthetic Fuels Corporation.[2]

The vision of energy security policy created by the political leaders and analysts of the 1970s was sufficiently compelling to withstand the passage of time, even the prudent judgment of hindsight. In 1982, Henry Kissinger, a consummate pragmatist on foreign policy, was moved to write: "Since the first price explosion of 1973, we have learned that the energy crisis is not a mere problem of transitional adjustment; it is a grave challenge to the political and economic structure of the free world."[3] This concept, the elevation of energy policy to the status of socioeconomic conflict involving a global scramble for strategic advantage, remained embedded in the energy policy debate for another decade.

Congress became especially adept at dramatizing energy policy. Senator Murkowski of Alaska commented during the course of a August 1990 hearing on the Iraqi crisis that "the ability of the United States to exercise its free will and to carry out its responsibilities as leader of the free world could be jeopardized by an excessive dependence on foreign oil imports." Senator Bentsen of Texas declared during the same hearing, "The United States is slipping inexorably into excessive dependence on foreign oil . . . we simply must stop this downward spiral into the abyss of energy dependence." And Senator Johnston of Louisiana stated in September 1990 that "we have allowed ourselves to become subject to the whims of the Persian Gulf dictators with respect to the lifeblood of our economy, oil."[4]

The terminology of energy security occasionally reached extreme forms of expression. Testifying before the House Subcommittee on Energy and Power in February 1991, Daniel

Yergin spoke of the "strategic significance of energy and oil," in 20th century history and went on to say:

> One important aspect of the second world war and one that has not been given a great deal of attention was that it was in certain ways an oil war. And if we had not won that oil war, it is questionable whether we would have won the overall war.[5]

Language as Prophecy

It would seem improbable, in retrospect, that the fate of nations should hinge on hydrocarbons and electrons and that a topic as technical and utilitarian as energy should inflame human passions. Energy is, after all, neither created nor destroyed but transformed by mechanical processes invented and managed entirely by humans. Access to energy supplies has not been problematic for most of human history, and any limitations encountered along the way of growth in energy demand have generally been overcome with new and better technology. Energy per se was not a security problem, even allowing for the overwrought social environment in which the term was first popularized. The United States had plenty of coal, natural gas, uranium, hydropower, and geothermal resources, as well as oil, when the 1973 oil embargo took place. And the energy crisis was, in retrospect, fundamentally a crisis of policy—Federal oil policy specifically—rather than a national, systemic failure. And yet the oil embargo precipitated a crisis of national confidence unseen since the Great Depression.

It is noteworthy that the 1973 and 1979 oil market disruptions were provoked not by a plan on the part of Arab members of OPEC to capture the oil market, nor by a strategy to maximize profits. The first oil embargo was, rather, an act designed solely for the purpose of influencing U.S. foreign policy in the Middle East. The actors in the drama were not corporate villains, and they were not a reincarnation of the oil trust monopolists of the early 20th century. The actors were leaders of governments, acting in concert, to transmit to the American Government a persuasive diplomatic message. It could be argued that oil, the agent of the message, was coincidental to the purpose. Oil was used as an instrument of foreign policy because the Arab governments involved had no other credible tool with which to capture American attention.[6]

The U.S. foreign policy establishment received the diplomatic message transmitted by the Arab members of OPEC, but concluded that the survival of the state of Israel represented a higher national priority than U.S.-Arab oil trade. What followed was not, as might have reasonably been expected, a U.S. engagement to address Arab grievances by foreign policy and security means. Rather, a diplomatic confrontation was transformed initially into a national obsession with U.S. dependence on all imported oil and subsequently into a tool for social engineering. The temporary oil embargoes of 1973 and 1979 inexplicably ignited a crusade about the moral foundation of American use of resources. Energy itself became the enemy, its use and overuse a measure of civic virtue or vice. The embargo also gave credence to the then-popular theory of limits; on natural resources sustainability, on economic development and growth, on the creation of economic wealth, and, most importantly, on human ability to manage human affairs.

Energy security remained a cornerstone of energy policy for over two decades. In its name, President Reagan opposed the construction of Russia's Yamal natural gas pipeline to Western Europe, declaring it a threat to the security interests of the entire Western Alliance. In the name of energy security, the domestic oil industry obtained subsidies for uneconomic wells; the coal industry secured Federal investments in coal liquefaction and gasification; the shale oil industry transferred its losses to the Federal budget; the ethanol industry was created by Congress and perennially subsidized; producers of unconventional gas were kept in business by tax subsidies even as over-producing conventional gas suppliers sought in vain for customers; and the manufacturers of every conceivable renewable energy system were kept from bankruptcy by Federal largesse.[7]

Energy security considerations also ensured the survival of the civilian nuclear power industry long after its rejection by the general public, and they played a part in the federalization of research and development for a new generation of coal-burning electric power plants. Notably, neither of these fuels had any relevance to energy security, an issue which, notwithstanding the broadness of the label, has always centered on U.S. dependence on imports of oil from the Persian Gulf. Nuclear and coal research subsidies have remained on the Federal budget books (below the line, in the deficit category) even as oil use in the electricity

generation sector served by these fuels has declined to the insignificant level of less than 700,000 barrels/day, out of the 17 million used daily by the entire U.S. economy.[8]

The Triumph of Policy

The energy security edifice of the United States was built on large expenditures of public funds. In the 20 years between the first energy crisis and the enactment of the Energy Policy Act of 1992, the Federal Government spent in excess of $100 billion on programs to enhance energy security. It built the Strategic Petroleum Reserve and invested yearly in research and development of virtually the entire plethora of energy supply and demand technology that could possibly contribute—cost competitively or not—to the elusive goal of energy security. Currently, one half of the annual $20 billion budget of the Department of Energy is devoted to energy research, development, demonstration, and commercialization of energy technology, notwithstanding the broadly competitive structure of the U.S. energy industry. These DOE budgetary expenditures are exclusive of the Treasury cost of subsidies to the energy sector, which have been estimated by the Energy Information Administration to range between $5 and $10 billion per year.[9]

The sum total of the last two decades of Federal energy outlays cannot be said to have measurably altered the energy security of the nation. The energy projects and programs embedded in the federal budget have engendered recurrent costs but have paid few dividends. The dividends have instead flowed from the consequences of good policy; these consequences were especially evident in 1986, when the power of the market drove oil to $9.00 per barrel. Throughout the 1970s, this price had been projected to reach, within a decade, a range of $60 to $100 per barrel. It was a victory of policy over programs; of free trade over protectionism; and of private competition over government direction and control. It was also a victory over OPEC.

The policy which defeated OPEC took 46 years to put in place, the period between enactment of the Connolly Hot Oil Act of 1935 and issuance of the executive order by which full decontrol of oil prices was accomplished in the first month of the Reagan administration. The U.S. Government's 1981 withdrawal from the business of oil left the field to spot and futures markets. The

efficiency and transparency of these markets have rendered the acts of governments, even of possibly colluding governments, increasingly irrelevant. It is noteworthy that the US. Congress debated the oil decontrol policy for the initial 6 years of the energy crisis, but created the Synthetic Fuels Corporation in a single session and in less than 1 year. Congress argued over decontrol of natural well-head prices for an even longer period, but established the $5 billion clean coal technology program in a matter of months.[10]

The Ghost of OPEC

OPEC remains an organization of governments. Although ineffective as a cartel operating in a global, generally free oil-trading system, OPEC continues to exert influence, psychological in the main, in excess of its market role. OPEC "reactions" to market price movements are still sought by industry observers and are reported as meaningful by organizations such as the International Energy Agency. And OPEC production decisions, though usually unconnected to operational reality in its member states, are still factored into traders' decisions during periods of abnormality such as labor strife at producing fields, emergency shutdowns of operating wells, or acts of war or natural disasters that impede deliveries of expected supplies.

Furthermore, and notwithstanding the organization's internal conflicts, OPEC members remain prone to collusion for political purposes. The last instance occurred at the outset of the Iraqi war, when OPEC's governing board waited for 25 days before releasing its members from production quota obligations, and "allowing" excess production capacity to be brought online. The OPEC decision, in that case, might have been nothing more than orchestrated political cover for members testing the lineup of opposition to Iraq. But the delay served to postpone the market's price adjustment to the loss of Iraqi and Kuwait production and earned OPEC members income unwarranted by actual market conditions. [11]

It would seem therefore reasonable for trading nations to seek the abolition of OPEC on the grounds that its existence and purpose are contrary to the objectives established by the international community in the General Agreement on Tariffs and Trade (GATT). OPEC members benefit from GATT but do not

reciprocate. Free trade, and adherence to free trade rules, encourage transparency in the economic relations of nations; illuminate instances of egregious political and economic behavior; and intensify scrutiny of nations' protection of the environment. In all these areas, and on human rights as well, OPEC members should be held to the same standards of conduct as those to which the international community adheres. They should be capable of economic competition on the merits of their national performance, and should be accountable for their economic and political behavior as sovereign nations rather than as indistinct members of a shadowy cartel.

The energy policy community could, for its part, consider abandoning the inflammatory frame of reference of energy security. Governments have more pressing, and more explicit security concerns than those that have come to be associated with access to oil supplies. Crises may indeed continue to be a part of what is increasingly a worldwide trading system in fuels and technology. But these need not, should not instigate a return to the security obsessions of the energy crisis era.

If history is any guide, it can be reasonably asserted that future turmoil in the Persian Gulf will not be resolved, mitigated, or otherwise affected by U.S. energy policy, however brilliantly conceived such a policy might be. Nor should linkages be drawn between emerging U.S.-Gulf politico-military agreements and oil policy. Producers as well as consumers have paid too high a price for the use of oil as a weapon of policy. The embargo of 1973 did not serve the long-term interests of Arab states in their relations with the United States. And the chaos created by Iran during the 1979 second oil shock proved, in 6 years, lethal to OPEC's oil income. The United States, for its part, has gained neither economic nor political advantage from its quest for energy security. It has, rather, saddled future generations with the cost of financing from the public purse the advantages that flow to the special interest energy community.

Conclusions

U.S. energy policy objectives have more frequently been fulfilled by adherence to market principles than by market interventions. On the security front, it might be prudently concluded that the interests of the nation have been better served by free trade than

by government design. A sector of the economy governed by technology and regulation, energy is a poor surrogate for foreign, defense and social policy. And, in any case, the goal of security, endlessly inconclusive like the work of Sisyphus, will likely remain beyond human reach.

Notes

1. C. Goodwin, et al., *Energy Policy in Perspective* (Brookings, 1981).
2. Senate Committee on Interior and Insular Affairs, Executive Energy Messages (Washington, DC: GPO,1975).
3. C. Ebinger, The Critical Link (Washington, DC: Ballinger, 1982).
4. Senate Committee on Energy and Natural Resources, *Hearings on Implications of the Middle Eastern Crisis for Near-term and Mid-Term Oil Supply*, 101st Congress, 2nd sess., September 1990.
5. House Subcommittee on Energy and Power, *Hearings on the National Energy Strategy*, February 1991, 102nd Cong., 2nd sess.
6. *Energy Policy in Perspective*, op. cit..
7. V. Stagliano, A *Policy of Discontent: The Making of the National Energy Strategy*, manuscript.
8. Energy Information Administration, *Annual Energy Outlook*.
9. EIA, *Federal Energy Subsidies: Direct and Indirect Interventions in Energy Markets*, 1992.
10. *Congressional Record*, 1979.
11. Stagliano, op. cit.

How Important Are Conservation and Renewables?

Kenneth G. Moore

TO THE EXTENT THAT ENERGY is a national security issue, what should be our driving concern? I've chosen to emphasize *predictability*, mainly because markets don't necessarily respond in purely logical, economic terms. Perception, driven by uncertainty, is often as important as actual economic factors, particularly when large numbers of people get emotional.

My office's contribution to solving the problem of energy vulnerability is basically a technology-based contribution. We hope to apply modern technology, within the foreseeable future, in a way that can be competitive in terms of cost with most currently used technologies. Moreover, we hope to find additional areas for improvements in efficiency that will increase the efficiency of energy use in the U.S. economy by up to a factor of two or three. A lot of folks would tell you that that's a pipe dream; at one time, I agreed. The issue of technology-based solutions to our energy worries has come up before—during the Nixon, Ford, and Carter energy plans—without amounting to much. However, I think we are finally closing in on the point where the technology is real, and we are taking a serious look at how we can practically apply it.

Kenneth G. Moore is currently the Director, Office of Planning and Assessment, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, where he is responsible for directing energy efficiency and renewable technology and program planning and evaluation efforts. Mr. Moore, a Navy veteran, was a licensed nuclear power plant operator and instructor within the Naval Reactors program and holds several military honors including the Navy Commendation, Navy Achievement, Naval Unit Commendation, and Meritorious Unit Commendation for contributions to military planning and programs.

In our view, energy efficiency is an important ingredient, which is often underemphasized in the mix of energy issues. Energy efficiency is not sweaters and fires, as Jimmy Carter would have had us believe; it has more to do with the optimal use of energy in the service of economic efficiency, and therefore productivity. My office is very interested in trying to improve domestic economic productivity. Not only is this important from the perspective of domestic living standards, but international strength depends upon a productive domestic economy.

Many in the United States would like this country to be less susceptible to outside driving factors. However, either from an energy security or an economic or an environmental point of view, it is hard to isolate the domestic economy from what is going on in the world. Improving our energy efficiency might give us some cushion against unexpected shocks in world energy markets. For example, according to one recent study, the 1973 price rise was a comparatively modest buildup over a relatively extended period of time, in comparison with the 1979 energy crisis. But its overall effect in terms of GNP was almost the same as the sharper but shorter spike in 1979, and the very short, almost panicked spike in 1990. For 1990, from an energy consumption point of view, the total direct cost was about $1.5 billion in the first 6 months after the event. Had we not made the efficiency improvements over the intervening years since the first energy crisis, the effect could have been about three times greater. It is also important to recognize the indirect consequences of such price shocks may be much larger than the direct effects. That's why overall effects on GNP can be orders of magnitude greater than the direct energy component.

I have recently chosen a set of numbers put out by the World Bank to illustrate my point about energy efficiency and productivity. In terms of GDP per primary energy use (expressed in kilograms of oil equivalent), the United States between 1971 and 1992 improved its productive capacity compared to energy consumption by factor of three. That is very good; it shows a lot of efficiency gain in the economy. On the other hand, Japan did an even better job of wringing the fat out of its economy during this period. By contrast, low-income countries have generally lagged.

On the other hand, in terms of the percentage of export earnings that in turn get re-applied to purchase imported energy, the United States has slid a little bit, to the point where 15 percent

of our export earnings are going to paying the bill for energy imports, while Japan's energy-related trade balance has improved. Once again, the low-income nations have not done so well. Together, these facts suggest to us that we have to keep one eye on U.S. economic competitiveness and the other on what some of those developing countries might do in terms of supply and demand. The IEA data—which are pretty conservative compared to several scholars—suggest that, because of population and economic growth in the less-developed countries, these countries' share of the overall world energy pie is likely to increase substantially (some say exponentially) in the foreseeable future.

The United States has made considerable progress in terms of energy efficiency; we have probably gained one BTU of efficiency for every one BTU of incremental supply we have brought on line since we started to address some of these energy efficiency issues. But it is important to recognize that, when talking about productivity gains, one has to look below the surface, because the sources of some of these gains are not always obvious. For example, about a third of our apparent efficiency gains are actually due to structural shifts within the economy: we are moving from heavy manufacturing to service industries. And even within manufacturing industries, U.S. producers are increasingly unlikely to undertake energy-intensive operations to produce raw goods; instead, we now tend to import raw goods with embedded energy value in them, and do the finishing.

Most of the forecasts promulgated these days foresee increased electrification within the U.S. economy. Against that backdrop, the Department of Energy foresees modest but significant growth in renewables, and substantial growth in the use of coal. This should be good news to those who worry about energy vulnerability, because such vulnerability is exacerbated by excessive dependence on a single fuel, which removes your options, and therefore your resiliency, when unexpected events come through the system.

The EIA mainstream forecast is by no means the lowest in terms of the projected growth of renewable energy sources, but neither by far is it the highest. My office has been using some of the standard models to address the question of how such forecasts would be affected if we were to meet the public goals and objectives that we have set for ourselves. Under a fairly optimistic

set of assumptions, we feel we could probably do a few percentage points better than the mainstream forecast. This would hardly be a revolution, but it does suggest that renewables could become a significant player. One of the reasons people like us and Shell Oil think that, if anything, the common wisdom tends to understate the growth of renewables is that R&D programs have been progressing very well in recent years and are driving the cost of renewables down toward a range in which they would be economically competitive with traditional energy sources.

While natural-gas-based technology is not necessarily the primary "competitor" for renewables, it is useful to note for illustrative purposes that we believe the economics of renewables are closing in upon the competitive range for this and other fuels. When we worry about the vulnerability of our economy to energy shocks, one of the primary areas of interest is the industrial sector. From the standpoint of diversity, the U.S. industrial sector is actually looking pretty good; we have a lot of basic fuel and power choices in that portion of the economy. But surprisingly, fewer and fewer players in this sector have second fuel choices; we think that this is probably because you wring some of your operating flexibility out of the system along with the waste that you are aiming to eliminate. So in terms of vulnerability, we have to consider on an ongoing basis whether future disruptions will have a larger effect (because of decreased flexibility) or a smaller effect (because of improved efficiency).

We have not yet solved the problem of our dependence upon imported oil, insofar as the Department of Defense of any other government agency can ever really solve it. At the moment, driving is getting cheaper in terms of the cost per mile traveled, and the total of light vehicle miles travelled in the United States is expanding at a substantial rate. This, of course, is significantly driving up most standard forecasts of the future demand for petroleum in the U.S. economy. We hope that shortly after the turn of the century, our technology-based strategies will begin to have a significant impact on the domestic energy scene. Of course, on that time scale, we cannot expect to reduce the overall requirement for petroleum. That will have to wait for significant changes in the structure of demand, particularly in transportation.

Discussion: Energy Vulnerability

John Riggs: In different ways, the three gentlemen who spoke on the issue of energy vulnerability represent the kinds of people who make policy work possible for people like me, from the political side of the table, who parachute in occasionally and must rely upon the wisdom of both academics and civil servants. When debating complex issues, politicians tend to look for pre-existing analyses that support our position, go right to the bottom line, and then, as someone once colorfully put it, "duel, with the bottom lines as our swords." People like Hill Huntington have done these sorts of analyses in the past, but then he and his colleagues at the Energy Modelling Forum did a dastardly thing: namely, they investigated why the assumptions of these models tend to vary so widely, and thus why we cannot selectively use them for our own ends. His work is good for the quality of public policy and public debate—even if it isn't so good for those of us who want to use scholarly work for political purposes. Vito Stagliano and Gary Moore represent the best of the civil service. People like them have enabled people like me to fake it over the years and act like we know what we're talking about.

Question: Do you believe that the U.S. and other governments have learned from the experiences of the 1970s, and that future policy responses to shocks in world energy (and specifically oil) markets will be more considered?

Vito Stagliano: You bring up the point of what is desirable to do as opposed to what actually gets done. I was deeply involved in the Bush administration's response to the Iraqi war, and I learned two things from that experience. First, I am not sanguine about the ability of Congress to stay out of the oil market. The overwhelming body of correspondence that we received from members of Congress during the first three weeks of the Iraqi oil embargo was in favor of re-introducing price controls. So I am not at all convinced that Congress can resist involvement in managing an

energy shock if the response of the administration is not to their liking.

Second, we had a difficult time getting the cabinet to agree on when would be the appropriate time to use the SPR. Half or more of the cabinet thought that, in doing so, we would be interfering with the market's attempts to find its own equilibrium. And of course, it is true that the market would eventually reach equilibrium if left undisturbed; if you let prices rise, demand will decrease, and the market will balance. But we had to point out to that half of the cabinet that the only purpose for which we had spent $20 billion to build the SPR in the first place was to *mitigate* that price shock that comes with a supply disruption. We were also required by diplomatic commitments to consult with the members of the International Energy Agency; so not only did we have to convince our own cabinet, but we had to get a consensus, which did not exist, at the IEA. In 1990, the IEA was looking, believe it or not, for actual physical shortages of oil somewhere, which in their mind would then trigger the need to release new supplies. But in a market without price controls such as that which prevailed in 1990, physical shortages are unlikely; rather, the effect of a disruption on supplies is felt through pressure on prices. But it required three months for us to persuade the IEA secretariat that the market was sending a signal through prices rather than physical shortages, and to gain their assent to release strategic stocks. So policy instruments are all relative in terms of their value and capabilities. And U.S. political dynamics are particularly volatile in difficult situations.

John Riggs: I would quarrel with Vito on one point. President Bush did a masterful job in bringing our allies along in a coalition to fight the war in the Gulf. With a little bit of leadership from the United States, I think we could have brought our allies along on energy policy as well, but I don't think we tried.

Vito Stagliano: I disagree. There was a very large investment of time made in getting that consensus at the IEA. It simply required all of that time to do it. Moreover, you cannot build a consensus among partners in Europe if you have this very strong division about policy within your own government.

John Riggs: That's my point; the paralysis within our own executive branch explains why we were unable to persuade the IEA in a timely fashion. This brings us back to a point mentioned by John Lyman this morning, that there seems to be some risk that our government simply will never use the SPR. In the current administration, we have taken the failure to use the Reserve in 1990 to heart, and have tried to forcefully state a policy of early use of our reserves, precisely for the reasons that have been articulated here. I can't guarantee that we will persuade everyone in the cabinet at the right time, but we have cleared this policy throughout the government. We hope we have educated some of the key players in advance, although as everyone in this room knows, when the decision to open the SPR is made, it won't be made by people at our level.

Question: Mr. Stagliano mentioned $9 per barrel as the "normal and natural price of oil"; on what do you base this assertion? Second, what trade policy instruments are available for combatting OPEC?

Vito Stagliano: I referred to the price of $9 per barrel as the "normal and natural price" of oil somewhat facetiously— although $9 strikes me as a perfectly reasonable price, given the costs of production, transportation, and so on. However, I do think the drop to $9 was an aberration, and adjustments ensued on both sides, in both supply and demand. Don't forget that U.S. oil production has been in decline since then, and that this shortfall of U.S. production had to be picked up by someone else. I think the present market price is more or less competitive, and to the extent that we know what the competitive price of oil might actually be, I do not see much exercise of market power by producers right now. In regards to your second question, the GATT system has very specific instruments to use against governments that behave in noncompetitive ways, primarily involving the imposition of sanctions and tariffs on these nations' products. Even better would be to seek, through negotiated means, an end to the OPEC cartel. Although I do not believe that OPEC wields much power over world oil markets anymore, its continued existence certainly gives the impression of political collusion. OPEC is not a trade association—it is a group of governments, and governments, generally speaking, cannot be trusted to refrain from colluding

when they see the opportunity. In the case of OPEC, I think it is fair to take them to the GATT table and ask them "If you are not colluding for political purposes, then what is the purpose of your organization? And if there is no purpose other than collusion, and you still want to participate in a global free trade system, why do you continue with it?"

Question: Do you believe the SPR is adequate to address the sorts of oil shocks that may possibly occur?

Vito Stagliano: My sense has always been that the SPR drawdown capacity has remained at 3.5 million barrels per day, and you can sustain that drawdown for up to 90 days; that strikes me as adequate to cope with ordinary supply disruptions in world markets. If there is a crisis anywhere in the world that from the very beginning gets you into an interruption of four or five million barrels per day, then I don't think that's a job for the SPR ; it's a job for the Marines. Some members of Congress were at first fond of criticizing President Bush because he was trading "blood for oil" in the Gulf, and it is easy to make that mistake of fusing foreign policy objectives with this vague notion of energy security. Clearly, there was an oil dimension to the crisis, but the U.S. and the rest of the world got by very well without that 4.3 million barrels of oil that were taken off the market *by our own actions.* The oil disruption question was a separate issue from the foreign policy objective of punishing blatant international aggression. But in the Congressional and popular mind, those distinctions were not at all clear, and people were arguing points about energy security and foreign policy objectives as if they were interchangeable, when in fact they are really quite separate.

John Riggs: I think it is true that at some level of disruption, it has gone beyond the SPR and it is a military problem. And frankly, I think the Defense Production Act would give the military access to all the oil they needed anywhere in our economy. However, I would disagree with Vito somewhat about what happened in 1990. At least at first, the primary foreign policy fear *was* closely tied to energy security, namely, that Iraq's army would continue through Kuwait and into Saudi Arabia. If Saddam Hussein had not waited for us to position our forces over there, we might have seen a much larger disruption. I also think it's unfair to take the least

well-informed opinions in the Congress as representative of the whole institution. Many of those in Congress who were berating the administration for inaction in responding to the economic threat posed by Iraq's actions were arguing on behalf of early use of SPR, rather than price controls. In fact, many were saying, "let's use the SPR so we can resist these guys who do want price controls."

Question: Please comment on the usefulness of the Defense Production Act?

Vito Stagliano: At the height of its involvement in *Desert Storm*, the military used about 1 million barrels of oil per day. Aside from the minor consideration that much of this was specialized jet fuel, 1 million barrels of oil was really nothing to worry about; the military went into the market and got it. Even if the military were to need twice as much oil per day for, say, a 6-month campaign on two fronts, I don't see that we need to do anything special to see to it that this oil is available.

Question: Can you foresee an end to U.S. dependence on imported oil? Congressman Sharp suggested this morning that this dependence would not be overcome in the foreseeable future at a price that Americans would be willing to pay.

John Riggs: I certainly don't see much easing of our appetite for oil in the next 30 years. At some point in the next century, however, the cost of alternative fuels will come down to the point at which we can significantly replace oil. I worked for Congressman Sharp for 20 years, and I think it is fair to say that he thinks in two-year increments, which is why he said that in the foreseeable future we cannot—through oil import fees, regulations, or anything else—significantly reduce our imports of seven or eight million barrels a day at a cost that is remotely acceptable to the American people.

Hill Huntington: When you ask for a time frame, I am reminded of the set of models used for the climate change issue, which go out to the year 2100. At least in their baseline case, I think their scenario is that oil eventually will be replaced by some sort of coal-based synthetic fuels—which of course brings on a new

problem, which is the carbon-emission problem. However, I believe that when you go out this far into the future, you are really in never-never land; but we should take note of the point that there may be other problems lurking in the shadows after we are finished with oil.

VI. Closing Thoughts

John Riggs

ENERGY SECURITY IS A COMPLEX CONCEPT, and we do ourselves a disservice if we start to think of it in narrow terms. It is not just fuel for the armed forces, although that's part of it. It is not just preventing cutoffs or interruptions of oil, although that's part of it. It is not just preserving our foreign policy options, although that is part of it. Perhaps the most important part of it is preventing harm to the U.S. and world economies from a price shock, but even that does not cover the whole concept. Increasingly, I believe that energy security is linked to environmental security, which different people define in different ways, but which we can't totally leave out of the equation.

Our attitudes toward energy security have matured quite a bit since we first discovered the topic in the 1970s. Back then, when we had the first price shocks, Democrats were interventionists, and, as Congressman Sharp acknowledged this morning, they overreacted. For example, on the basis of faulty projections, they probably invested too much in energy in both the private sector and the government and thus wasted a lot of resources. That was the "Chicken Little" response to threats to our energy security.

In the 1980s, we moved too far in the other direction under President Reagan. We adopted a *laissez-faire* approach to energy security that insisted there was no role for government—with the single exception of advocating more nuclear power—and probably invested too little in energy. That was the "Dr. Pangloss" school of energy management: "All is for the best in this best of all possible worlds."

Mr. Riggs is Acting Assistant Secretary for Policy, U.S. Department of Energy. He was appointed Principal Deputy Assistant Secretary for Policy, U.S. Department of Energy, in June 1993. For the previous 12 years, he was Staff Director of the Energy and Power Subcommittee, which had principal responsibility in the House of Representatives for the passage of the Energy Policy Act of 1992.

By the 1990s, I think we had come to a synthesis between the parties, between liberals and conservatives. It led to the Energy Policy Act, which was an initiative of a Republican administration passed by a Democratic Congress. It acknowledged that markets were the principal way to deal with energy problems, but that markets were not an altar at which we should worship; they were a tool. There are still ways in which the government can and should intervene: for environmental reasons, for energy security reasons, for long-term economic competitiveness reasons, and in the R&D area. But where we want to intervene, we have learned to try to do it by using the market, rather than heavy-handed regulation.

I think we still have the potential for additional crises such as we had in the 1970s and in 1990. At no time have we been able to predict what the next crisis would look like, and this prescience eludes us to this day. For example, would any one of us have believed before 1990 that the third oil crisis would result because *we* embargoed *them*? Energy shocks can and will evolve in ways that we cannot predict, and we need to be nimble and fast on our feet and have on hand market-based ways to respond when that crisis occurs. I think we all believe that the Saudis have learned the economic lesson that they could not drive prices up, because they would lose their market. But economics does not always determine the actions of governments; there could be political or military or religious reasons why a government would do something that was not in their economic interest.

Let me now mention a few specific points from some of the presentations today. First, I think the emphasis on markets may have been in some ways overstated. As we have acknowledged here, today's price is probably not a market price. If the Saudis can produce oil at $2 or $3 per barrel and we're paying $17 or $18, there is something other than market forces at work there. Maybe it's the ghost of OPEC; I frankly don't know what it is, but the point is that we are not paying a true market price. So I'm not sure we should base all our responses on the assumption that, whatever happens, that's the will of the markets and we should not do anything about it. I do recognize, however, that many of the things we might be tempted to do about it would do more harm than good, so we may need to accept it.

It was also mentioned that the government should be willing to sponsor new technologies through the startup phase but not to

continue such subsidies once the "precompetitive" stage is past. But who is supposed to define the crossover point at which it becomes a "bad subsidy" rather than a "good incentive" to a new technology? As an example, I would ask if something like the oil depletion allowance or foreign tax credits for oil producers are in the category of the bad subsidies that we should not be continuing. Each person would identify subsidies in a different way.

I think it is a bit presumptuous for us exclusively to stress economics and markets at the expense of politics and social goals. Economists tend to think that public policy decisions should be based on economic reasoning; but in a democracy, it is the public's values that matter, and if the public chooses to value noneconomic factors more highly, that is what the government is obligated to respond to. That may mean that sometimes we take short-run actions that don't pay off in the long term.

The argument that the SPR may not be worth the investment because we are unlikely to actually use it has already been discussed. I hope that we will use it. But I believe that if we once again walked up to the brink and then backed away, this argument would be valid, because we would have lost all credibility with the markets. Regarding a related issue that brought up in the discussion of energy vulnerability, I think there is a good case for using buffer stocks to prevent major price spikes, rather than just for the more extreme cases of physical shortages or strategic interventions. That doesn't mean that we should intervene in the market every time the price moves a dollar or two, but there's nothing wrong with using our SPR stocks to prevent the harm to our economy that results from large price spikes.

In the second panel, there was a mention of the growing demand for OPEC oil. I am not sure that anyone mentioned the increasing concentration of the world's known reserves (as opposed to production) in four or five Gulf countries. If that is where the excess capacity is indeed located in the next few decades, I think that means that we could have the potential for future price shocks, and should be prepared.

I was also a little puzzled by the concept of "special relationships," whether it was between China and Iran, between Russia and some of the other former Soviet republics, or whatever. I'm not sure how the emergence of such relationships could be consistent with the underlying assumption, shared by practically all

of the panel members, that the market is what allocates supplies. Will there be special relationships in which one country sells another oil at a price that is lower than what prevails in the world market? Or are such relationships just a form of political posturing with little substantive content?

The projections of future nuclear capacity in the United States also raised a few questions in my mind. First (and I realize of course that no forecaster can predict this), if there were to be another serious accident like Chernobyl, what would that do through the political system to force the early retirement of more nuclear plants? Second and more immediate, what effect will increasing competition in the electricity-generating sector have on those nuclear facilities that have higher operating costs? Will some of these become uneconomic to run, and what will that then do to our capacity over the next couple of decades?

In response to the charge that energy security is an empty concept that serves only to perpetuate bad, self-serving public policy, I would like to recall what Mark Twain said about Wagner's music: "It's not as bad as it sounds." Clearly, bad things have been done in the name of energy security. But I submit that we should criticize the misuse of the concept of energy security, not the concept itself. People have misused it to justify all sorts of bad policies, and one of my favorite comments on this issue was one that was made by Danny Boggs when he was Deputy Secretary of Energy. He said that the use of the concept of energy security to justify all sorts of pork-barrel projects reminded him of a country-and-western song, "Calling It Love is No Excuse For What We're Doing." Likewise, calling it energy security was no excuse for pushing some of these policies. At the same time, just because some of the rhetoric was inflated at the time of the first couple of oil shocks does not mean that they were insignificant. Significant economic harm was inflicted upon our country. True, much (although certainly not all) of this harm arose because we resorted to price controls, the first time in particular, but I don't think we should minimize the effect that these shocks had on our economy, and therefore the potential effects that a future shock could have.

For example, one statement made by a U.S. senator was considered rather inflated: "The ability of the U.S. to exercise its free will and to carry out its responsibilities as leader of the free world could be jeopardized by an excessive dependence on foreign oil

imports." To me, that sounds true, and I'm not just saying that because that very same senator is now going to be chairman of our authorizing committee. I do believe that our ability to act in the foreign policy arena can be restricted by political and economic considerations arising from our appetite for imported oil. Former Energy Secretary Schlesinger used a good illustration: if we had been in a tight oil market in the mid-1980s, would we have opted to bomb Libya? Whether or not you think that this was the right thing to do under the circumstances, we might not have been willing to do that if we thought that it might lead to another oil price shock. So our energy vulnerability does, I believe, impose limits on our foreign policy options in some cases.

Annex

Identifying Future Courses for Crises

M. T. Freund, J. A. Wise, C. A. Ulibarri, B. R. Shaw, H. E. Seely, and J. M. Roop

THIS PAPER ADDRESSES U.S. ENERGY security in the post-Cold War era for a conference on energy security jointly sponsored by the Department of Energy and the National Defense University. It examines the evolving nature of energy security based on analysis of past crisis-inducing events and discusses potentially important geopolitical, environmental, regulatory, and economic developments during the next 25 years.

The paper steps beyond the traditional economic focus of energy security issues to examine the interplay between fundamental economic and technical drivers on one hand, and political, environmental, and perceptual phenomena on the other, that can combine to create crises where none was expected. The paper expands on the premise that the recent demise of the Soviet Union and other changing world conditions have created a new set of energy dynamics, and that it is imperative that the United States revise its energy security perspective accordingly. It proceeds by reviewing key factors that comprise the concepts of "energy security" and "energy crisis" and how they may fit into the new world energy security equation.

The study also presents a series of crisis scenarios that could develop during the next 25 years, paying particular attention to mechanisms and linked crisis causes and responses. It concludes with a discussion of factors that may serve to warn analysts and decision makers of impending future crises conditions.

The crisis scenarios contained in this report should be viewed only as a representative sample of the types of situations that

could occur. They serve to illustrate the variety of factors that can coalesce to produce a "crisis." This study focuses primarily on the following issues:

- Geopolitical and regional developments affecting the stability of major energy-producing states
- International energy consumption patterns and international energy production among major producer blocs
- Financial markets and their role on the price and availability of energy products
- The effects of environmental regulation on energy security.

This paper views the role of petroleum in the world energy security equation as primary. While other energy fuels such as coal, natural gas, nuclear, or renewables remain important, fewer concerns are attached to the security of their supply or pricing. Thus, it is real or perceived interruptions in the supply of oil, and the associated consequences that would accompany such developments, that are expected to be the principal focus of U.S. energy security for the next quarter century.

Energy security will be a key national security issue during the next 25 years. This paper presents the case that in the post-Cold War era, the traditional concept of energy security requires modification in order to facilitate effective recognition, management, and deterrence of future energy crises. The authors' approach takes into account the wide array of changes that have occurred since the 1973 energy crisis, and the need to adjust the U.S. energy security focus accordingly. Based on an examination of the dynamics of past crisis situations and the possible direction of future crises outlined in this paper, we have developed an approach that broadens the scope of energy security and thus establishes a foundation on which to help direct future analyses concerning U.S. energy security in the 21st century. The following is a summary of the major findings.

- It is the interaction of crisis-stimulating events and responses to these events that together generate energy crises. The total state of a recognized "energy crisis" cannot be attributed to a single occurrence, such as an energy resource supply disruption. Crisis-initiating events and responses to those events are intrinsically linked. Real or perceived supply disruptions or threats to supply are a main source of crisis stimulants. Responses to such stimulants are linked via positive feedback mechanisms, and thereby snowball as a result of

fear or uncertainty on the part of governments, producers, and consumers. These, in turn, create and often exaggerate a state of crisis conditions. Perceptions play a critical role in the advent of crises.

- The end of the Cold War and collapse of the Soviet Union has dramatically altered the international environment in which energy security is sought. Many states are now largely free of superpower constraints, and seek to pursue their own national interests, not those of a patron state. This evolving situation heightens the prospect of regional conflicts, including potentially destabilizing conflicts over natural resources such as water, agricultural land, or petroleum in energy-producing regions.
- Energy security is an international issue. It is difficult to isolate many of the energy security interests of the United States from those of other major energy-producer and consumer states. Interdependence between producers and consumers and their joint desire to provide long-term unimpeded access to energy products provides a basis for establishing global energy security. The international character of the petroleum industry along with the interaction of, and the sharing of, perspectives between producers, consumers, and markets can help foster stability. Despite these convergent interests, pure political and other nonenergy related interests will remain primary determinants for the policies and actions of many states.
- Past experience demonstrates that unpredictable international circumstances have the potential to stimulate energy crises, and are likely to develop with minimal warning. Ensuring effective energy security therefore resembles risk management. The United States should have an infrastructure in place to conduct crisis management and mitigation actions on short notice. Defusing misperceptions is central to avoiding crises. This might entail ensuring the distribution of accurate energy information to financial markets or other large consuming states in the event of geopolitical developments, or establishing better ways to utilize strategic petroleum reserves.
- The fuel of primary importance to U.S. energy security during the next 25 years will continue to be petroleum, primarily as the result of the large and growing transportation

sector throughout the world which is wholly reliant upon petroleum. As domestic supplies of petroleum are depleted, American reliance on imports will grow, thus making the United States susceptible to international developments that might affect the price and availability of oil.

- The Middle East will remain the most important international source for petroleum resources due to its large petroleum reserves, the quality of those supplies, and the relative ease with which its oil can be produced. This region also will continue to exhibit political instability related to the Arab-Israeli conflict, the spread of Islamic extremism, territorial disputes, and other issues. Political developments in this region will remain unpredictable.
- Portions of the Former Soviet Union (FSU) show significant promise for development as alternative suppliers of fossil fuel energy resources. But serious concerns exist regarding the issue of political stability. The need to attract capital and technology for the ailing FSU energy sector heightens the risk associated with projected reliance on those resources as a major source of supply.
- Turkey is expected to play a growing role in the international energy security equation because of its strategic geographic location, vis-a-vis the development and export of petroleum reserves in Central Asia.

Need for a New Concept

The meaning of energy security for the United States in the post-Cold War era will be different than previously conceived because of worldwide changes in politics, economics, technology, and the environment on a global scale. These changes have altered the forces that might create future energy crises and the context within which such crises might arise. These changes have also altered the appropriate path U.S. policies should follow to address potential future crises. Traditional concepts developed during the past, therefore, require modification in order to respond to funamental changes on the international scene.

The collapse of the Soviet Union has significantly changed external military threats to energy-producing regions on which the United States has traditionally depended and created conditions wherein some of the newly independent states of the FSU might

become major exporters of energy resources to world energy markets. Yet, there are serious questions concerning burgeoning economic and political instabilities throughout the FSU and whether the FSU's energy sector will be able to obtain the Western capital and technology it needs to modernize and compete on a global scale.

While unique circumstances surrounded its creation, the establishment of the Gulf War coalition following Iraq's 1990 invasion of Kuwait demonstrated the growing shared interest and interdependence between major energy-producing and consuming states and their ability to cooperate in seeking mutually acceptable conditions for energy security. The Iraqi incursion also demonstrated how in the post-Cold War era, the absence of superpower constraints over client states may enhance the prospects for regional military conflict involving energy resources. In addition, while diplomatic progress on the Arab-Israeli peace front shows promise to remove a principal cause of tension in the energy resource-rich Middle East, political turbulence there will persist, creating obstacles to energy security.

There is a growing worldwide recognition of the importance of the environment and the need to include ecological considerations in plans for economic growth and industrial development. Concerns over environmental degradation are influencing the development of existing and emerging alternative sources of energy. Growing public sensitivity to the environmental impacts of energy production, transportation, storage, and use have led to broadened regulatory oversight that influences our ability to achieve energy security.

Interdependence between energy-producing and consuming nations has grown as the result of the globalization of financial energy markets, and the increasing involvement of large producers in downstream activities. Meanwhile, technological advancements in energy resource extraction and recovery have improved the ratio of known energy reserves to production. Deep- water drilling techniques, for example, are now able to profitably access reservoirs of oil previously untapped because of excessive cost.

The concept of an energy crisis must move beyond thecomfortable and simplistic analytical framework that focuses almost exclusively on singular events resulting in supply-side disruptions of crude oil (e.g., protecting U.S. access to Persian Gulf oil). The next world energy crisis might, indeed, have its roots in sudden geopolitical developments in the volatile Middle East, leading to concerns over the availability of energy resources. But it is equally plausible that a crisis might develop from turbulent political developments occurring simultaneously in several other world regions, or build gradually and less visibly as the result of the interaction of more subtle forces; perhaps revolving around economic conditions or environmental concerns. It is our contention that the key to recognizing and avoiding future crises lies in understanding their complexities and underlying dynamics and in being aware of how less obvious forces (frequently within our control) combine to create crisis circumstances.

A primary theme of this paper is that energy crises may have no single cause or villain, but rather evolve from the confluence of crisis-initiating events and the coupled responses to, and perceptions of, those events. Supply disruptions of crude oil (either real or perceived) frequently play an important role but are not the sole cause of crises. Actors such as the U.S. Government, other major energy-consuming states, private industry, financial markets, and the general public respond to this uncertainty, frequently driven by fear over the future availability of that resource. Recognizing and monitoring response mechanisms help illuminate the recursive dynamics that precipitate energy crises and the inherent linkage between crisis causes and responses in the crisis "state." Understanding this process will allow for the development of remedial or avoidance measures that will form the basis of future energy security policy.

Achieving energy security for the United States during the next 25 years will require a broadened approach to the topic. The revised rationale will not rely solely on market externalities, but rather the need to monitor, assess, and take decisive action to preclude inappropriate responses from the variety of market actors. Such an approach may have more in common with the practice of risk management of complex systems than with traditional notions of security oriented toward specific threats from a fixed set of sources. Unforeseen events can be expected to develop in the future from a wide range of sources with the

potential to precipitate crises. The ability of the United States to view unfolding developments within the proper perspective and to take appropriate corrective measures (in unison with other nations) will facilitate the effective management or deterrence of severe crises.

Oil will remain the energy resource of greatest importance for the immediate future, and the United States and the consuming world are likely to remain heavily reliant on the Middle East for much of their energy needs. Without the development of alternative major supply sources from other world regions, this dependence will only grow with time. Thus, sensitivity to destabilizing political developments in the Middle East—especially the Persian Gulf—will remain intense. Reduced dependence on the Middle East as a primary source for oil, or diplomatic initiatives that help stabilize that region as a secure energy producer, would enhance the prospects for future energy security. The development of large energy resources for export from Russia, Azerbaijan, and Kazakhstan would be an immense benefit. However, internal strife, ethnic conflicts, and political and economic instability throughout Russia and the FSU may also introduce new uncertainties into the world energy supply balance.

The end of the Cold War and depolarization of the world has ushered in changes that will affect global energy security. Foremost among these are the removal of many outside superpower constraints imposed on client states. Nations are now freer to pursue their own national interests. One related outgrowth could be the increased proliferation of nuclear weapons programs by developing states seeking prestige and protection against regional adversaries. Proliferants may seek to establish secret nuclear weapons programs under the guise of peaceful nuclear power generation activities. A related concern is the possible diversion of nuclear technology, fissile materials, or even a nuclear device from the FSU to proliferant states. In addition, conflicts previously suppressed by superpower intercession could escalate when the interests of states clash, such as those related to the control of energy resources. Competing claims over oil deposits in the South China Sea between China and Vietnam could be one such flashpoint. While a greater United Nations role in coming years may help moderate some of these conflicts, the inability of that world body to achieve consensus on divisive issues may undermine its ability to intercede decisively.

Developing a new framework for energy security in the changing post-Cold War era requires a fresh approach to the subject commensurate with the complexity of the post-Cold War world, while at the same time building on lessons learned from the past. While this does not invalidate all prior energy security concepts, it does require that they be adjusted against world conditions that have changed significantly since their inception. This means refocusing of our efforts; moving away from the analysis of singular events toward an understanding of the world energy situation as a whole, and the dynamic forces that shape it.

Disruptions in the supply of oil have normally been seen as the root cause of energy crises, although it has become apparent that the dynamics of recent energy crises have been driven as much by perceptions or fear of potential long-term energy shortages, as by meaningful actual shortages of significant duration. Most resource appraisals addressing global crude oil availability estimate abundant resources for more than the next twenty-five years (for example, see Miller 1992; Barnes 1990; Masters 1993; Houghton et al. 1993; and Attanasi and Root 1994). Therefore, a key component of energy security in the post-Cold War era is recognizing that most potential supply shortages are likely to be of temporary duration and that the ability of the United States and other major consuming nations to rapidly tap into alternative energy sources will enhance our energy security posture. Crises, almost by definition, are transient events.

While the major thrust of this paper is to view energy security from a broader perspective than just the economic one, economic issues cannot be ignored. It is important to consider the relationships among oil inventories, prices, and the demand and supply of oil as it affects energy security. These topics have a familiar and fundamental importance in analyses of oil supply disruptions and the continued dependence of the United States on foreign oil to meet its energy needs.

First, the United States derives 38 percent of its energy needs from oil, and this is not likely to change substantially over the next decade. Second, traditional relationships between oil stocks, prices, and demand/supply, have evolved to keep pace with the institutional changes in the structure of oil markets, and these changes are important to understanding how prices may respond during crises. Third, oil supply sources have changed dramatically over the last two decades, bringing new opportunities to diversify

America's import energy basket, and reducing the risk of oil supply disruptions on the American economy. Finally, the reality of continued dependency on foreign oil, now 41 percent of total U.S. petroleum consumption, warrants some consideration of what our demand for foreign oil means to other countries, and what foreign demands for oil mean to the U.S. economy.

Toward a New Energy Crisis Paradigm

Typically, crises develop when an unanticipated shortfall (or perceived shortfall) of energy resource occurs and the "ramp-up" time for replacing the supply is compromised by excessive cost or time delay. Total demand at any given time is served by a number of sources. The loss of any one or more sources may create an immediate shortfall. The time and cost of the replacement from either the current source or additional new sources and the market responses to these times and costs constitute the depth and severity of the "crisis." That is the fundamental, economic side of the crisis. This precipitating event may then be complicated by a series of factors.

For example, the Iranian Revolution in 1978-79 removed approximately 3.7 million barrels of oil per day for 6 months. The cost of the makeup from other sources, allocation difficulties, and concern regarding political instability in the Persian Gulf led to panic buying, gas lines, and price surges. While increased Organization of Petroleum Exporting Countries (OPEC) production made up for approximately half the Iranian shortfall, supply tightened further because there was not an adequate system to disseminate accurate market information and assuage panic buying. As a contrast, the Iraqi invasion of Kuwait in 1990 removed 5.4 million barrels of oil per day for 10 months, and yet, in part because of rapid source make-up from Saudi Arabia, and widespread publicity associated with mobilization of the Desert Shield/Desert Storm alliance, the market crisis that occurred was of limited duration. One major difference between the Iranian Revolution and Gulf War circumstances was the widely held perception that the relationship between the Kingdom of Saudi Arabia and the United States had changed. The two states were able to work cooperatively in 1990. The Saudis announced that they would make up the shortfall, and their ability to do this was

guaranteed by American-led protection against an Iraqi incursion into the Saudi oil fields.

Energy crises germinate through a sequence of interwoven events and responses based on perceptions, not through any singular objective external event. Actions by the U.S. Government, private industry, and the general public may exacerbate these effects, thereby fostering crisis conditions. Further, the interaction of several seemingly unrelated events over time, none of which alone would facilitate a supply restriction, have also generated crisis situations through mutually-reinforcing mechanisms. In the literature on analyses of accidents occurring in highly complex technical systems, this process of converging and amplifying system effects has come to be called the "normal accident" because of its pervasiveness. Under analogous conditions, an energy crisis forms just as does a cascading failure in a complex technical system.

Perceptions of current developments and anticipated future influences in the international energy marketplace are taking on greater importance. Futures trading activities in oil, now an important component of the international energy security equation, is at times driven by psychological pressures derived from fears and uncertainty over provocative international developments. For example, the confrontation between the international community and North Korea over Pyongyang's apparent nuclear weapons program has helped force up the price of oil futures, leading at least one petroleum market specialist to note the importance of "psychological pressures" and "anxiety" in the market.[1]

Given the fact that rapid changes have altered the complexion of the post-Cold War world, and that reactions and perceptions to real or perceived supply shortages contribute to the onset of crisis conditions, a more expansive concept of today's energy security equation is needed. This framework should be based on the ideas that:

- Economics alone cannot explain energy crises. Economics, politics, and other factors such as technology and the environment need to be considered in unison.
- Energy crises are transient in nature; the price increase associated with market response will encourage forces that lead to an end to the crisis.

- Discussions concerning energy security should recognize that despite the interdependence of energy-producers and consumers, states develop and maintain legitimate and unique national interests based upon their own particular social, political, and economic needs. Understanding such differences will help avoid misperceptions which can promote or exacerbate potential crises.
- Energy crises are promoted by the same drivers underlying the "tragedy of the commons," whereby nations acting in their own self-interest attempt to maximize gains while competing for scarce resources.[2]

Traditionally, energy security has focused on supply-side analysis of Middle East oil and on preventing the FSU from gaining undue control or influence in the region. But under current evolving conditions, expectations over future energy costs, resource availability, and the environmental impacts of energy resource use are displacing these preexisting concerns. In the post-Cold War era, bipolar models of political influence are no longer relevant, and the nature of friendly and adversarial relations are increasingly ambiguous. Outside superpower influences that previously constrained the actions of states embroiled in the East-West conflict have largely been removed, allowing these states increased liberty to pursue their own self-interests. This will result in a less predictable international environment, where numerous opportunities will exist for states to clash over conflicting interests.

Accordingly in the post-Cold War era, energy crises will result from a combination of events, perceptions, and the subsequent actions or reactions of independent governments, private industry, and the general public. It is these "linked components" that in unison act to produce a crisis. Thus:

- Energy security concerns the overall state of a country's energy system in terms of its production, transmission, storage, and consumption activities that enables energy markets to function as efficient mechanisms for allocating energy resources, *but also promote or constrain the scope of the nation's independence of action.* The fundamental economic indicators of energy security include:
  - technical performance and efficiency in resource availability, and in energy production, transmission, storage, and use;

- the presence of energy resource and capacity constraints, and ongoing efforts to develop alternative or substitute sources of energy; and
- the strategic end-use of energy by source, location, and type. These factors must be monitored to understand the fundamental movements in the energy markets over the long term and to uncover the precursors to crisis conditions.

• Energy security is jeopardized by a loss of perceived control over energy product availability, and/or distribution, and/or delivery that:

- starts with a specific event and subsequent responses to the event (e.g., panic buying, regulatory controls or halts in futures market trading);
- expands through public oversimplification and uncertainty concerning these events and responses;
- impairs the ability of the United States and/or other key states to function militarily, politically, or economically; and
- is a transient condition, although the impact(s) may linger. Clear information about what is happening to demand as well as supplies in the short term, and clear communication of this information to the public will help control the more egregious perception problems that force governments to intervene in energy markets or in political disputes when vital interests are not actually at stake.

• Energy security in the post-Cold War era necessitates:

- movement away from the idea that only supply-side disruption events generate crisis conditions;
- more recognition of how perceptions promote behavioral responses which magnify energy crises; and
- the realization that energy crises arise through initiating events, but subsequently depend on the responses and interactions of various political, financial-economic, technical, and environmentally-centered forces. Enough is now known concerning many of the demand-side economic reactions and political reactions to permit governments to devise strategies and tactics to respond appropriately not only to perceived

supply disruptions, but to the constellation of other reactions that surround them.

- The behavioral response components of an energy crisis highlight the roles of key players in the U.S. energy security equation. Particularly important roles include:
  - government responses such as the regulation of domestic energy production, distribution, and consumption; the importation of oil and the use of import tariffs and price regulation; and the use of a full range of economic, political and even military sanctions;
  - market responses, such as panic buying and selling of energy-related commodities, and their respective futures and options markets;
  - industry responses, such as changes in energy production, consumption, exploration, and R&D activities as well as profit-taking and other opportunistic market-trading activities; and
  - responses by the general public and/or special interest groups such as outcries over environmental accidents (e.g., Three Mile Island or the Exxon Valdez) and unpopular regulatory measures (e.g., gas rationing and tariffs).

Awareness of the interactive nature of these key players and their response actions is central to understanding how crises develop and, subsequently, how crises can be recognized in their formative stages and their effects diminished or mitigated.

The interlinked roles of initiator and response that may create an energy crisis was illustrated following Iraq's invasion of Kuwait in August of 1990. Following the invasion, the spot price of oil leapt from $16 a barrel to around $36 a barrel. Market mechanisms had responded rapidly to the *perceived threat* to Persian Gulf oil supplies. In the United States, releases from the Strategic Petroleum Reserve (SPR), which was at an all-time high, did not occur until shortly after the air war against Iraq began in late January of 1991. This was a slow-acting response; not to the perceived threat of short-term shortages, but to the high spot price of oil. Subsequent economic analyses of the period have criticized this delay as being "too little, too late" to blunt the impact of the price rise produced by the market's sharp response to the initial situation.

In the above sequence of events, no single cause of the temporary energy crisis can be isolated. The perceived threat to Middle East oil supply was a contributing factor, as was the rapid response by the market to perceived future scarcity. Another contributing factor may have been the failure of the United States, as the world's largest consumer of foreign oil, and other International Energy Agency (IEA) members to help stabilize the market sooner through the release of strategic petroleum reserves.

The cause of energy crises rests in the interaction of a cascading sequence of initiators and multiple responses to them. The actions of people, markets, and nations do not occur in a direct sequence, such as an automobile production line. The interaction of responses on different levels of the social scale, with different delay times due to the mechanisms by which they operate, are affected by unintended feedback, and are mostly uncoordinated. They rely on different information sources and become sources in turn for subsequent actions. In combination, however, these responses exert significant influences, greater than the sum total of their respective impacts. This collective set of evolving conditions all contribute to the set of conditions labeled "a crisis." Just as importantly, in the middle of these conditions, governmental decision makers frequently lack an overarching, comprehensive view of the situation, which hampers their ability to take decisive actions.

High-speed telecommunications and responsive information systems have resulted in the world being much more densely connected, so that news of potential threats to energy stability and reactions to them now proliferate much more rapidly through financial markets, responsible government agencies, and public awareness. This makes it inevitable that energy security in the 21st century will have much more in common with risk management of complex systems than it will with traditional notions of security, oriented around specific threats from a fixed set of sources. The effective management of response mechanisms will help facilitate more accurate perceptions in world energy markets, and therefore reduce distortions and minimize over-reactive, crisis-inducing behavior.

Annex

Historical Sketches: Seeing the Future in the Past

The following review of key historical events sheds light on the genesis of past energy crises and how the interaction of initiating events and responses precipitated crisis conditions for the United States and others. While many of these crisis events are thought to have been caused by simple supply disruptions or technical system failures, the following review illustrates the importance of systemic crisis dynamics. As previously noted, these dynamics will play an even greater role in energy security and crisis management and avoidance in the changing post-Cold War world environment.

The 1973 Arab Oil Embargo

A series of diplomatic misperceptions and unanticipated consequences of U.S. support for Israel during the October 1973 Yom Kippur War led Arab members of OPEC to cut production and halt shipments of oil to the United States, South Africa, Portugal, and the Netherlands. The embargo was accompanied by decreased OPEC production, during a time when there was minimal excess production capacity elsewhere in the world. For the United States, the embargo occurred at a time of rising demand, increasing imports, and declining domestic oil production. This resulted in short-term shortages (gas lines) and dramatic price increases.

These events occurred despite the fact that at the height of the 6-month embargo, the net loss of supplies was 4.4 million barrels per day, or only about 9 percent of the total 50.8 million barrels per day that previously had been available in the "free world" (Yergin 1991). To some degree, international oil companies were able to reroute oil from other exporters to the embargoed countries (Fried and Trezise 1993). However, the embargo's effects were magnified by tremendous uncertainty about how much oil actually was available. Confusion in the market, coupled with widespread uncertainty about the future supply of Middle East oil, led to panic buying, further exacerbating the shortage.

One of the lessons learned from the 1973 embargo was that energy supply shocks can be significant and psychologically

enduring despite being measurably small and transitory. In part, this may be owed to rising world consumption of oil (7.5 percent a year) at the time of the shock (Yergin 1991). The 1973 embargo also demonstrated how dangerously reliant the United States had become on foreign petroleum sources, without an accompanying knowledge of the ramifications of this vulnerability. This lack of understanding was partly the result of perverse government incentives of taxing domestic oil and gas production, while simultaneously subsidizing oil imports. Regulatory responses also bore much of the blame, as an allocation system had been introduced just prior to the embargo. This system, meant to ensure even nationwide supply, had the opposite effect, preventing redistribution of the supply to points of need. Thus, the reduction of supply, small in comparison to that withdrawn from the market as a result of Iraq's 1990 invasion of Kuwait, was not the sole cause for the severity of the crisis. Rather, it was the responses of markets, producers, and regulators that exacerbated conditions.

The 1978-1980 Iranian Revolution and Outbreak of the Iran-Iraq War

The Iranian Revolution began with protests and violent acts directed against the Pahlavi monarchy in 1978. By late that year, a strike by oil workers virtually shut down production and halted exports. While the signs of serious political instability were building in Iran throughout 1978, the United States was distracted by other foreign policy issues, such as the Camp David peace accords between Israel and Egypt, strategic arms negotiations with the Soviet Union, and normalizing ties with China. World supplies appeared to be tight, as the winter demand surge was beginning while the inventories of international petroleum companies were low (Yergin 1991). Despite this fact, significant levels of lost Iranian production were offset initially by increased production by other OPEC members (primarily Saudi Arabia). A total deficit in supply of 2 million barrels per day ensued initially, or 4.3 percent of consumption in the oil-importing countries (Fried and Trezise).

However, panic spread following the fall of the Shah in January 1979. The Iranian monarch had been considered the strongest proponent of American and Western interests in the region. His ouster was both unexpected and traumatic. It was feared that the new regime would indefinitely halt Iranian oil

production and that its radical, anti-Western Islamic doctrine might spread to other Muslim countries, particularly the Arab oil-exporting states of the Persian Gulf. This precipitated panic buying in the West and by Japan. Spot market prices increased and oil companies scrambled to build stocks in anticipation of further price increases. OPEC then raised official prices, precipitating a further upward price spiral. The rush to build oil company stocks, reinforced by heightened consumer demand and intense uncertainty regarding political conditions in Iran and elsewhere in the Middle East, resulted in an artificial increase in world demand of 3 million barrels per day above actual consumption, further exacerbating the sense of crisis (Yergin 1991).

In September 1980, Iraq invaded Iran, producing yet another serious disturbance in the Persian Gulf. Iraq gained control of portions of the key Iranian oil province of Khuzestan and struck at and damaged Iranian oil production and transportation facilities. Iran retaliated in kind, inflicting significant damage on Iraq's oil production and transportation infrastructure. Crude oil prices remained high throughout the early stages of the war, as concerns mounted that the conflict might escalate and that the resulting instability in the Gulf might prompt a total shutdown of exports from the region. Many Gulf producers reduced output, while oil companies and governments began to stockpile oil to build reserves (EIA 1993a). Those combined actions put upward pressure on prices, which rose from $14 per barrel at the start of 1979 to more than $35 per barrel in January 1981.

The back-to-back occurrance of these two events in 1978-1980 magnified uncertainty and speculation regarding the future availability of Persian Gulf oil, as did the continuation of the Iran-Iraq war throughout much of the 1980s. *The creation of additional "demand" in excess of actual world consumption requirements also demonstrated how crisis responses feed on one another, making circumstances appear worse than they actually are.*

The 1979 Three Mile Island Release Incident and the 1986 Chernobyl Nuclear Reactor Explosion

In March 1979, a small pressure relief valve in the primary feedwater system in Unit 2 of the Three Mile Island (TMI) Nuclear Plant stuck open, causing a loss of coolant and eventual depressurization of the reactor. The crew and managing teams from the

Nuclear Regulatory Commission did not assess the state of the plant and the ongoing processes correctly, and the water level dropped until the nuclear core was partially exposed and severely damaged. A meltdown of the core was narrowly avoided. Three Mile Island resulted in a total release of radioactivity of 2.4 million to 13 million curies, of which only 13 to 17 curies of radioactive iodine were released to the environment. The negligible physical consequences outside the plant were overwhelmed by the social and psychological impact on the U.S. public, where faith in the safety of nuclear power was badly shaken. Independent assessments afterwards concluded that the causes were mostly compounded "human error" because of inadequacies in equipment design, information presentation, emergency procedures, and training.

In April 1986, operators at Unit 4 of the V.I. Lenin four-reactor complex near the village of Chernobyl in Ukraine were conducting an experiment, running the reactor with the emergency water cooling system deliberately turned off. After a series of human errors, an explosion occurred, releasing about 50 million curies of Strontium-90 and Cesium-137 which dispersed throughout Europe and North America. Some reports indicate that as many as 10,000 people in the FSU may have died from the associated effects of radiation poisoning. Another 10 million probably were contaminated.

The impact of these incidents transformed public attitudes about the safety of nuclear power and threatened support for the global nuclear industry and its acceptance as an alternative energy source. This is especially significant because the large-scale adoption of nuclear power had been seen as the United States' technological solution to the energy supply disruptions of the type occurring during 1973 oil embargo. Other countries had also perceived the advent of nuclear power as the answer to their lack of fossil fuel deposits or the technologies needed to cost effectively recover them. Combined with the as yet unsolved technical problem of long-term storage of radioactive wastes, these highly publicized accidents served to alter the public's image of nuclear power.

Although some have argued that nuclear power must return to the United States to meet the next century's demands for increased electrification, one lesson of the last twenty years is that a solely technical solution of shifting demand to an alternative

energy source is unlikely to provide a stable solution to questions of energy security. Furthermore, serious safety concerns remain over the continued usage in the FSU of nuclear power reactors similar or identical to the flawed and unstable Chernobyl reactor design. The danger remains that another disaster could disperse radioactivity across much of Europe.[3]

The 1988 British Piper Alpha Oil Platform Explosion

In July 1988, a gas leak at the $3 billion British Piper Alpha offshore oil drilling platform in the North Sea caused an explosion which demolished the structure and killed 167 workers. The oil industry's worst disaster caused a disruption in oil recovery of about 400,000 barrels a day over a period of two months, and raised serious safety questions concerning deep sea oil drilling. Accident reconstruction analyses showed design flaws in the platform. The Piper Alpha explosion was widely used as an example of how time pressures in the exploitation of petroleum resources from the North Sea had led to an unusually high rate of industrial accidents. This, in turn, stimulated a continuing argument of productivity versus safety in offshore drilling operations that has slowed the licensing and siting of such platforms and increased the cost of recovering North Sea oil. As with accidents in the nuclear industry, the design and operations of offshore oil platforms are being challenged. Another major accident and spill could have devastating consequences for the industry in terms of public acceptability of offshore oil drilling. *The lessons of Piper Alpha illustrate that social support for extracting natural resources becomes bound with the willingness to accept the occupational safety and health risks that accompany the enterprise.*

The 1989 Exxon Valdez Oil Spill

In March 1989, in Prince William Sound, Alaska, the Exxon Valdez tanker struck a reef and spilled 11 million gallons of her 53-million-gallon crude oil cargo. The spill fouled four national wildlife refuges, a national forest, and three national parks, invading more than 1,200 miles of coastline. Extensive media coverage over the following weeks emphasized the Alaskan wilderness and its wildlife despoiled by crude oil. It was the largest and most expensive U.S. tanker spill in history, eventually costing over a billion dollars in cleanup and an estimated 100,000 dead sea birds, plus as yet

uncalculated damage to salmon and herring hatcheries and seal and sea otter populations. To date, Exxon has paid out about $3 billion in damage claims. The litigation on another $3.5 billion in damages continues, and much of the scientific evidence gathered on the effects of the spill and its aftermath is sequestered awaiting court testimony.

While the ultimate environmental effects are in dispute, there is little disagreement over the impact of the Exxon Valdez spill on the American public, whose perceptions of the environmental/technical safety of oil production were altered. This had direct adverse consequences for what is politically possible in the domestic supply arena, and could have precipitated a "crisis," had the supply/demand balance been more precarious. Oil drilling and transport in ecologically pristine and fragile areas have come into disrepute, and the search for alternative energy forms has been given a noticeable boost. Major political battles have forestalled further oil drilling in Alaska, while Congress has attempted to respond with legislation requiring detailed inspection and control of tanker operations and training for crews. The oil industry has proposed to build five coastal response centers around the United States to handle future spills, while the strong environmental lobbies see the only hope to avert such future disasters is to lessen the country's oil needs. The Exxon Valdez created a highly charged image of economic-driven despoliation of the planet. The consequent public attitudes and perceptions of "big oil" are raising questions as to domestic oil production in our energy future. The same lack of public support constrains federal support for long-term petroleum research on technologies that could help recover the 100 billion barrels of oil still available, but not economically retrievable, from previously worked U.S. fields.

The 1991 Gulf War

The August 1990 Iraqi invasion of Kuwait forced the price of crude oil to rise suddenly. A United Nations embargo on all crude oil and products from both countries shortly thereafter increased fears of large shortfalls and stimulated additional price increases. Iraqi and Kuwaiti production totaled some 4.3 million barrels per day, representing almost 7 percent of world supplies (EIA 1993a). World crude prices rose from $16 per barrel in July 1990 to $36 a barrel in September of that year. In response, Saudi Arabia and other OPEC members increased production, as did non-OPEC countries

in Central America, Western Europe, the Far East, and in the United States, offsetting much of the shortfall. At the time, commercial stocks in Organization for Economic Cooperation and Development (OECD) countries were abnormally high (Fried and Trezise 1993).

No apparent increase in speculation occurred in futures markets in the 90 days immediately following the invasion, as these markets did not contribute to the run-up in prices or to price volatility (EIA 1993a). Prices fell following United Nations approval of the use of force against Iraq in October 1990, after only a 2-month price escalation. In January 1991, the beginning of the allied air war against Iraq precipitated a record drop in world oil prices, as fears of a cut-off of Persian Gulf oil diminished. The announcement, shortly after the allied offensive began, of the International Energy Agency (IEA) agreement to release up to 2 million barrels per day from government-held stocks, also served to moderate concerns (Fried and Trezise 1993). As a result, only about one-third of the pledged IEA strategic stocks were actually sold. The release of further stocks by both Saudi Arabia and Iran also served to help calm oil markets.

The rise in price of crude oil and petroleum products immediately following the Iraqi incursion into Kuwait reflected multiple uncertainties. These included the possible spread of the invasion (south into the Saudi oil fields), the potential destruction of Persian Gulf oil installations in the event of war between Iraq and the allied forces, and the spare capacity available to OPEC and other world producers to replace lost Kuwaiti and Iraqi supplies. The success of the allied coalition to mobilize militarily and obtain the necessary political backing to confront Iraq, coupled with the immediate battlefield success of the Operation *Desert Storm* offensive, helped prevent a further price escalation in world markets. Perhaps most importantly, IEA discussions on the release of strategic petroleum reserves of member states provided a psychological restraint to runaway panic buying. While the timing of the IEA intention to release stocks was geared to preempt panic in the early stages of the allied offensive, there are those that argue an earlier such announcement would have had an increased moderating effect on world markets in the lead up to the conflict. *In the final analysis, the effects of the 1990-91 Gulf*

crisis were modest in comparison to previous crises as a result of the availability of increased and more detailed oil market information and close cooperation among major energy consumers and between consumers and major producing states.

Energy Crisis Scenarios: Better Understanding the Paths to Potential Crises

A series of potential scenarios could induce an energy crisis during the next 25 years. Illustrative scenarios fall into the following categories, according to their primary causal mechanism:

- Political: regime changes, terrorism, civil unrest, and regional conflict, including conflicts between states arising from contested control over natural resources.
- Environmental and technical: changes in environmental regulation as a result of accidents or emerging scientific understanding, transportation disruptions due to technical failure.
- Economic: rapid and sustained economic development among the world's emerging economies, dollar devaluation, failure to fully develop FSU energy resources.

Previous energy security studies have focused on long-range prediction concerning geopolitical developments, energy resource availability, and international economic conditions and have largely failed to predict the onset of subsequent crisis conditions, which are *short-term phenomena arising out of perceptions and uncertainties and are compounded by the choice of responses based on these perceptions and uncertainties.* Many key developments affecting U.S. energy security during the past twenty-five years have been sudden and unexpected. Based on past experience, it can be assumed that previously unidentified crises types and/or well-defined crisis conditions may occur in the future with little forewarning.

As the politically volatile Middle East contains 65 percent of the world's proven oil reserves, that area will continue to merit significant attention. This is especially true of the Persian Gulf region, where the vast majority of Middle East oil is located. The importance of Middle East oil will be further magnified should future instabilities in other parts of the world lead to an increased

concentration of available world supply in that region. Large known petroleum reserves and anticipated future finds located in Russia and elsewhere in the FSU make that area an important energy region. Developments in Latin America and Asia also warrant close scrutiny as significant energy reserves are located there, as are growing energy-consuming populations.

During the next 25 years, potential energy crises could result from single, regional supply- side disruptions of significant proportion. Equally likely are crisis situations evolving out of a linked series of events that individually would not result in crisis, but in unison have that effect. Finally, crises might build over a period of time, as the convergence of a variety of seemingly unrelated environmental, energy, social, and technology policy consequences gradually exercises interlinked constraints on the energy system.

Political

It is essential to monitor and attempt to predict the potential for, and consequences of, conflict and geopolitical change that may impact energy security, while at the same time recognizing that international political events are inherently complicated and are frequently difficult to foresee with great specificity.

Regime changes. Changes of central authority may occur in states precipitating a worldwide energy supply shortage and/or the destabilization of energy-producing regions. Worst-case scenarios envisage such changes occurring with little warning. *Unforeseen and rapid regime changes can serve to magnify associated political and economic uncertainties, resulting in unsettled public concerns regarding the long-term availability of energy products.* Sudden and dramatic regime changes are likely to have the greatest psychological impact on energy markets.

Regional conflict/civil unrest. Armed conflicts or significant levels of civil unrest in major energy-exporting countries might result in crisis conditions if sizeable levels of petroleum or other energy resources were kept from the market (or such a threat appeared imminent) and sufficient excess production appeared to be unavailable from other producers/regions. Were conflicts to arise in more than one energy-producing region simultaneously, severe crisis conditions could result. *Increased consideration*

should be given to the possibility that crises may evolve from several small-scale, concurrent conflicts in separate world regions.

Terrorism. Major acts of terrorism generating widespread international publicity could help the onset of an energy crisis. *Terrorist actions resulting in extreme environmental damage and/or loss of human life could trigger societal or political responses that influence the range of acceptable alternatives for energy production.* Use of more or less oil, worldwide, as a consequence of such events, could result (DOE 1992a).

Terrorism does not have to make sense; it just has to attract attention. As long as the United States continues with per capita consumption of twice that of Europe and six times that of the world as a whole, the energy production, supply, and distribution facilities that support it remain tempting targets to extremist factions seeking to justify themselves to disenfranchised people everywhere. In this respect, probably the most dangerous terrorist weapon would be a small nuclear device aimed at a key juncture point in the production or supply of oil. The possible proliferation of nuclear technologies to recognized states that support terrorism thus becomes a key concern of future energy security.

Environmental/Technical

The adverse environmental effects of various forms of world energy production, transportation, and use has generated concerns in the United States and overseas, resulting in increased public sensitivity to environmental issues.

Restrictive environmental regulation. The growing political strength and influence of the environmental movement could lead to more restrictive activities in the future, especially should more significant environmental degradation come to pass.

Technical (transportation). Nearly half of the 66 million barrels per day of oil consumed worldwide flows through one or more of six key tanker routes (*Oil & Gas Journal* 1994c). A disruption of crude oil or product shipments through key world shipping lanes at choke points such as the Strait of Hormuz (where 14 million barrels per day transit), Strait of Malacca (7 million barrels per day), the Suez Canal (900,000 barrels per day), Panama Canal (500,000 barrels per day), Rotterdam Harbor (600,000 barrels per day), or through the Bosporus (1.6 million barrels per day), could

result in a crisis, according to an Energy Information Administration study (*Oil & Gas Journal* 1994c).

Economic

Adverse international economic conditions could develop gradually or over a short period of time, helping to precipitate crisis conditions. Understanding and learning to recognize non-obvious interactions can help establish warning signs of crisis conditions that may be building, enabling corrective or preventative measures to be employed.

Rapid economic growth. Sustained and dramatic economic growth by developing countries in Asia and Latin America during the next twenty-five years could put strains on world energy markets and contribute to the onset of crisis conditions. These conditions could arise either out of the continuing development (and growing energy appetites) of the world's poorer economies, or out of an unexpectedly poor performance by the energy sector of the FSU.

Dollar devaluation. A massive devaluation of the U.S. dollar could result in crisis should foreign energy sources become prohibitively expensive, especially should producing countries choose to benchmark the price of crude against another foreign currency.

Lessons Learned: Commonalities Across Energy Crises

These scenario types and future energy trends for the United States and the world suggest that although there are many possibilities for energy crises in the post-Cold War world, there are also commonalities and distinguishing characteristics of the conditions that create them. Awareness of these commonalities may help illuminate the early development of precursor conditions to a crisis, while also helping us comprehend how sometimes seemingly distant developments in either time or subject matter may interact to produce crisis conditions.

The preceding sections highlight the key forces and dynamics of past energy crisis situations and possible future scenarios. They illustrate that the interaction of multiple factors in response to crisis-stimulating events serve to exacerbate those situations and

elevate their impact. Further awareness and understanding of those factors will allow for earlier recognition of future crisis developments and/or more effective management of crisis conditions when they occur. These key factors include:

- **Fear and uncertainty regarding political instability in major energy-producing regions exacerbates energy crises.** Regional conflicts are likely to grow in the post-Cold War era, and we must be prepared to manage and deflect their effects. Wherever possible, preemptive diplomacy and mediation may halt the advent of destabilizing armed conflict. Under special conditions, the use of military force may be required to protect our energy security interests.
- **Immediately available energy production, supply, and distribution information to world markets during times of perceived crisis improves policy reactions and reduces market impacts.** As demonstrated during the recent Gulf War, closer cooperation between markets and producer and consuming states helps moderate panic reactions.
- **Concern over adverse environmental impacts from energy production, transportation and use can contribute to energy supply disruption.** The proper balance must be sought between protection of the environment from irreversible damage, and the need to responsibly utilize available natural energy resources. Continued research into the use of large-scale, environmentally-friendly energy sources must also be pursued. U.S. Department of Energy (DOE) intelligence resources could be effectively utilized to help monitor and assess situations from which concerns over adverse environmental impacts emanate.
- **Every political crisis is a potential energy crisis if it occurs in a major energy-producing region of the world.** Potential energy crises may arise from the results of internal or regional instability. Border disputes, ethnic and religious strife, or succession uncertainties also appear to be prime candidates for creating conditions that may occasion an energy crisis, through perceived impacts alone, if not real ones. Particular attention should be devoted to the impact of hostilities on key energy production and distribution facilities, with developments in the Persian Gulf and FSU meriting significant monitoring.

- **Energy policy in the United States, and elsewhere, is increasingly likely to be influenced by environmental policy.** The United States leads the world in the implementation of meaningful environmental regulations, such as in the area of clean fuel emissions reduction. However, such actions have unforeseen consequences, the end results of which may increasingly put the production of energy under control of a system which is not yet well organized, and which is buffeted by significant social disputes. This serves to make prediction of energy needs and savings accruing from energy programs more difficult, driving down the comprehensibility of the energy system to the analyst. Recent delays by the U.S. Environmental Protection Agency (EPA), for example, to settle on disposal means for older fluorescent tubes, which are classified as hazardous waste due to their mercury content, caused a significant slowdown in the commercial sector's changeover to energy-efficient lamps. Similar examples in EPA's administration of the Clean Air Act amendments have caused confusion with many utilities' demand-side management programs that have raised the cost of those programs over five times earlier estimates. Projected energy savings too often assume perfect planning and implementation of the scheme, which is hardly ever realized in the real world. If those energy savings are being critically counted upon to reduce demand for an energy resource, their absence may be enough to trigger or exacerbate an energy crisis.
- **In the short run, perception is everything to the energy marketplace.** The marketplace responds to real or imagined crisis initiators with attempts by buyers to secure energy resources in the face of uncertainty. For uncertainties about resource supply, the ensuing response of the marketplace then acts to create the shortage in the near-term, whether or not one exists in reality.
- **Technologically and environmentally speaking, there is no "free lunch."** It is tempting to look for the solutions to future energy problems in terms of simple fuel substitutions. In 1973, nuclear power was supposed to offer the kind of energy-secure future that natural gas is promised to deliver today. But all sources of energy have their costs. Hydroelectric dams interfere with salmon runs. Wind power projects are criticized for their visual and sonic impacts and their potential threat to

wildlife. As the number of environmental and social concerns associated with energy projects grows to include such considerations as "environmental justice" and equitable distribution of benefits, the likelihood diminishes that any single fuel source will be able to meet all objections to its conceivable uses.

- **Transferring energy requirements from one fuel source to another does not solve an energy problem, but merely shifts it to a different sector of our energy economy**. This is especially true as regards oil and natural gas. If unforeseen technological breakthroughs allowed a massive shift to electric cars, and the need to curtail burning of fossil fuels demanded it, there would be a concomitant energy crisis in trying to meet the electrical demand over the grid.
- **Economic policy matters because it helps control the precursors to crisis**. Economic growth of developing countries will be a major driver of national and international energy policy in the future. That development will exacerbate the potential for conflicts over natural resources, and perhaps result in increased competition of developing countries with the United States for foreign energy resources. The more that developing countries are encouraged and assisted to develop in a "sustainable manner," the less pressure there will be to consume non-renewable energy sources, and energy security for all will be enhanced. The health of the U.S. dollar could also be an energy issue. With our current and increasing dependence on foreign energy sources, a strong dollar on the international money markets is needed to keep the costs of foreign-obtained energy affordable.

Critical Foresight

Charting a course to future energy security will be gained through seeking to establish a dynamic equilibrium among the forces that can create energy crises. Maintaining the balance requires sensing the recurrent combinations of crisis conditions and reading the trends towards situations that constrain our energy-related policies and their responsiveness to crisis events.

The revised conception of energy security developed in this paper can be illustrated through use of a seafaring metaphor. In this metaphor, energy security is not a destination, it is a journey.

And what has changed is the seascape on which the journey is taken.

In the past 50 years, we have sailed a course analogous to that of a journey downriver. The boundaries of the course of energy security were often well defined by the opposing riverbanks of competing world hegemonies. The very forces of history it seemed, provided an impetus to the passageway. If new energy resources appeared, like islands in the stream, the question was to which side of the channel, and thus which hegemony, they would belong to as the ship swept by.

The end of the Cold War and the dissolution of one of the world's great political empires is tantamount to the ship reaching the river's mouth and finding itself on a great, uncharted sea. Without the nearby shorelines, how will the course be discerned, what rules of steerage will be invoked, and what are the unforeseen dangers of continuing the journey?

Our scenarios show that the variety of conditions that can prompt crises, the multilevel responses the United States and other countries and world energy markets make in turn, and the associated operational time scales of the above, are much greater than before. The world has become a much more uncertain and confusing place, if not a more dangerous one. Continuing with the seascape metaphor, the following are the rules of "good seamanship" that we believe advisable when journeying on such uncharted domain.

Keep Landmarks in View

One of the basic rules of open water sailing is to keep landmarks in view if you don't have a chart. Landmarks in the energy security sense are given by clear statements and communication of priorities. These priorities need to address the degree to which the nation will decouple energy supply and consumption, and the mixed use of energy resources we will strive to achieve. If they can be clearly communicated and implemented, it will become easier to maintain awareness of the precursors of national and international circumstances that may threaten our ability to meet these goals.

Know the Indicators of Currents

The earliest open water sailors learned quickly to follow the route of the trade winds and currents if these were taking them generally where they wanted to go. Similarly, it appears that energy security may be guaranteed far more by sensing and working with emerging world drivers of energy consumption than by trying to resist them. Two of the strongest emerging drivers of energy use in the world are the environmental consequences of different fuels and the energy needs of developing countries. Charting a course that is compatible with these realities is one that is inherently more secure.

Keep Watch for Whirlpools, Icebergs, and Other Surface Disturbances

To a sailor, all of the above are phenomena due to conditions beyond control of the ship's crew. But running into these is a function of steerage. In our metaphor, a "whirlpool" is formed by a conflict in at least two convergent sources of control. On the sea, these may be currents, while on a world energy surface, they may be competing religious ideologies or political rivalries in an energy-producing region, or even incompatibilities in the operations of our own federal agencies.

Icebergs are what the name implies—a major obstruction to passage that may be only partly visible from the surface. But when struck, they do not yield, and will significantly deflect a course. Public opinion and values are much like icebergs in that the depth of opposition to a proposed plan of action is often not apparent from a distance. But when aroused, public opposition can greatly change the course of energy development in a country, as the history of our nuclear industry shows.

Surface disturbances are indicators that there is something going on out of view which may mean danger for the unwitting voyager. Good sailors "read the ripples" to infer what water conditions go unseen. Similarly, effective guidance in energy matters means becoming aware as early as possible of the risks inherent in certain approaches to energy security. These may be risks in the suitability or effectiveness of proposed energy technologies, or uncertainties in the results of environmental modelling, such as predicted world climate changes, that nonetheless affect energy security goals.

Be Prepared for the "Killer Wave"

The "killer wave" is a sea phenomenon that appears to come out of nowhere on clear, calm days to swamp the unfortunate boat. It is an "interaction phenomenon" caused by a chance confluence of circumstances and forces that converge at a particular point. While it is documented and real, it is relatively unpredictable in terms of the exact location and place it can strike. Similarly, an energy crisis can occur or be amplified through the chance interaction of many smaller effects, each of which would not trigger a crisis. The Arab oil embargo of 1973, as deliberate and monolithic as it appears, in hindsight actually was occasioned in its timing and impacts by just such an interplay of relatively independent world conditions and small details that made it the "killer wave" it was for U.S. energy practice.

Although impossible to predict with exactitude, it should be possible to extract a key set of semiindependent indicators for certain types of metaphorical "killer wave" phenomena with respect to energy security. This set of indicators would combine summary conditions of world financial energy markets, trends in energy demands, concentration ratios of energy resources for certain uses, and indices of social stability to give an overall reading of the suitability of conditions for a "killer wave."

Exercise Foul Weather Preparedness

No country can predict or avoid all potential energy crises. Being "foul weather prepared" means having plans in place to deal with the worst and most unpredictable of these, so that mitigating actions may be taken properly and within the time required for reactions. Just as failing to reef a sail in time can overturn a ship, responses to crisis conditions are not useful if they are delayed. Implementing crisis plans means having the information necessary to do the right thing at the right time. Acquiring that information and getting it to governmental and private sector decision makers is a provision of energy security that needs to be practiced and maintained.

Know Where the Safe Harbors are on the Journey

It is said that countries do not have friends, they have interests. A safe harbor on the course of energy security is gained by knowing which countries have compatible energy interests to one's own,

and how these might be built into alliances that act concertedly to remove threats to energy security. The Iraqi occupation of Kuwait was overturned by an alliance of nations that had a convergence of interests and concerns. It had to be painstakingly built over a period of time. Effective alliances are deterrents to the kind of adventurism that may occasion energy crises. Making and maintaining these alliances will be another essential part of energy security in the changed world order of the 21st century.

Conclusions

Achieving and maintaining energy security in the post-Cold War era will be both an evolutionary and an adaptive process. It will necessitate building from the advantage of hindsight and its accompanying lessons learned from past crises. It will also necessitate recognition of potential crisis-inducing developments on the international scene, reducing their likelihood where possible (e.g., by reducing dependence on foreign oil by both the United States and developing world), anticipating and planning contingency actions ("war gaming" the Strategic Petroleum Reserve, for example), and compensating for them as they occur. It will inevitably be, to some extent, a learn-as-you-go procedure.

Our review of past events illustrates that much of the excess severity of previous crises were directly attributable to reactions about perceived shortages of energy supply based largely upon fear and uncertainty over the future availability of oil, not from actual supply shortfalls. Other crises impacts were due to the combined influences of relatively minor stimulating events and the interlinked responses to them from agencies acting with good intentions but with little information or coordination. Certain past incidents that have not stimulated energy crises, per se, have occasioned changes in public attitudes and the regulatory environment that could become crucial in the formation of a future energy crisis. Information that is accurate and more effectively communicated concerning the actual market facts, both ahead of time and during the crisis, offers a better chance to defuse potential crises.

Severe energy crises appear to manifest themselves in at least three ways:

1. They arise from perceptions and psychological responses to perceived uncertainty in the future price or supply of a resource.
2. They arise from a cascading set of stimulating actions and responses in energy and financial markets and governmental agencies that tend to produce the crisis as an emergent consequence from all of the activity.
3. They build slowly and relatively imperceptibly over time, as a variety of seemingly unrelated policies, decisions, and changes in the world all act to constrain effective responsiveness to a future critical incident, which then becomes a trigger for an unreasonably massive impact.

These are all aspects of a dynamic world energy security equation. The previous focus of most energy security analyses have dealt extensively with crisis stimulants, as if these were somehow enough to explain all the consequences. They are not, even when the initiating event seems to be clear and distinguishable. Rather, the so-called critical incident or initiating event always has its own history of precedents and consequences, all of which radiate outward across time and distance to collaboratively create the course of the crisis.

One thing that *is* certain in all of this dynamism is that it is not an "us against them" world, whether we think of the dichotomy as energy consumers versus producers, or one bloc of consumers against others. Energy security will not be realized by simply substituting a new oppositional thinking for the old. In the new world order, energy-producing and energy-consuming nations are both interested in avoiding circumstances that might interrupt supply and therefore threaten their respective financial/economic well-being. Everyone benefits from a world energy security equation that projects smoothly and foreseeably into the future. What this means is that the energy security of the United States becomes inextricably bound with the energy (and even political) security of other nations. There is no clear boundary where distinct relevancies become apparent. Instead, the overlapping and competing interests in world energy resources bump and rebound and sometimes adhere, making for a complex and continually evolving worldset of influences.

- Forecasting under such circumstances would seem to be exceptionally risky. Yet, certain of these influences also seem inevitable because they are driven by inexorable

demographics, or they are already in formation. China and other Asian nations will exhibit strong growth in energy consumption, particularly for transportation and electrification. So will many of the developing countries.

- There will be periods of political turbulence in the FSU and in the Middle East. The former is recovering from 75 years of spent political orthodoxy, the latter from the pressures of booming population, economic growth, and ongoing regional tensions.
- Economic development and environmental concerns will become increasingly linked, as the industrial practices of any one nation have increasingly obvious consequences for others.
- Throughout the next half century, the world will begin to look ahead to a transition to a post-oil energy economy, as the cost of remaining fossil fuels rises with an inevitable decrease in reserves and an increase in the environmental impacts of their continued use.
- Issues of the safe use of nuclear power and its potential support of nuclear proliferation will have to be addressed in a consistent way on a world scale, to prevent the possibility of future Chernobyls and nuclear arms races among the developing countries.

These and other forces will create the currents that can become courses to crises. As their uncertainty and variability increase, the ability of the United States to exercise its diplomacy adaptively and flexibly becomes all the more important, as does the need to think systemically and to integrate activities across our different agencies of government. But there is no one sure route across such an uncharted sea, only practices of good "seamanship." It is hoped that this paper will help provide the stimulus for the analysis and the vision that will guide that journey.

Notes

1. A. Myerson,"Oil Price is Highest in a Year," *The New York Times*, June 16, 1994.
2. G. Hardin, "The Tragedy of the Commons" *Science* 162.
3. D. Jehl, "Ukraine Hints It Won't Close Nuclear Plants at Chernobyl," *The New York Times*, June 13, 1994.

Works Cited

American Petroleum Institute. January 1994. *Basic Petroleum Data Book, Petroleum Industry Statistics.*

Attanasi, E. D., and D. H. Root. 1994. "The Enigma of Oil and Gas Field Growth." *Bulletin of the American Association of Petroleum Geologists,* Vol. 78, No. 3.

Barnes. 1990. "The OIES Review of Long-Term Energy Supplies." *Oxford Institute for Energy Studies, Oxford.* United Kingdom.

Bohi, D. R., and W. D. Montgomery. 1982. *Oil Prices, Energy Security, and Import Policy.* Resources for the Future, Inc.

Bohi, D., and M. Russell. 1975. *U.S. Energy Policy: Alternatives for Security.* Resources for the Future.

Brauchli, M. September 14, 1993. "China's Oil Needs Outstrip Its Supply." *The Wall Street Journal.*

British Petroleum. June 1993. *BP Statistical Review of World Energy.*

Clark, J. 1990. *The Political Economy of World Energy.* University of North Carolina Press.

Commodity Futures Trading Commission Annual Report (CFTC). 1990. Chicago Board of Trade.

Conway, P. April 1994. "Kazakhstan: Land of Opportunity." *Current History.*

Cremer, J., and D. Salehi-Isfahani. 1991. *Models of the Oil Market.* Harwood Academic Publishers.

Curlee, T. R., and M. Russell. 1992. *Oil Vulnerability, Structural Market Changes, and the Role of the U.S. DOE.* Oak Ridge National Laboratory.

Doran, C., Buck, S., eds. 1991. *The Gulf, Energy, and Global Security: Political and Economic Issues.* Lynne Rienner Publishers.

Dornbusch, R. and J. Poterba. 1991. *Global warming: Economic Policy Responses.* MIT Press.

Dunkerly, J. 1978. *International Comparisons of Energy Consumption.* Resources for the Future.

Dunkerly, J. 1980. *Trends in Energy Use in Industrial Societies: An Overview.* Resources for the Future.

The Economist. June 18, 1994. "Survey: Energy."

Energy Information Administration (EIA), U.S. Department of Energy. 1992a. *Country Profiles: 1992.* Washington, D.C.

Energy Information Administration (EIA), U.S. Department of Energy. 1992b. *EIA Analysis Brief: The Former Soviet Republics.* Washington, D.C.

Energy Information Administration (EIA), U.S. Department of Energy. May 1993. *State Energy Data Report 1991 Consumption Estimates.*

Energy Information Administration (EIA), U.S. Department of Energy. September 1993a. *The U.S. Petroleum Industry: Past as Prologue 1970-1992.* Washington, D.C.

Energy Information Administration (EIA), U.S. Department of Energy. October 1993b. *Weekly Petroleum Status Report.*

Energy Information Administration (EIA), U.S. Department of Energy. January 1994. *Monthly Energy Review.*

French, H. E., and W. C. Lee. *Quarterly Journal of Economics.* February 1987. "The Welfare Cost of Rationing-by-Queing Across Markets: Theory and Estimates from the U.S. Gasoline Crisis."

Fried, E., and P. Trezise. 1993. *Oil Security: Retrospect and Prospect.* The Brookings Institution.

Friedman, T. April 3, 1994. "OPEC's Lonely at the Tap, but China's Getting Thirsty." *The New York Times.*

General Accounting Office (GAO). 1993. *Energy Security and Policy: Analysis of the Pricing of Crude Oil and Petroleum Products.* Washington, D.C.

Hirshleifer, J., and A. Glazer. 1992. *Price, Theory and Applications.* Prentice Hall, Inc.

Horwich, G. June 1991. "Energy Policy, Oil Markets, and the Mid-East War: Did We Learn the Lessons of the 1970's?" Draft working paper. Purdue University.

Houghton, J. C., G. L. Dolton., R. F. Mast., C. D. Masters., and D. H. Root. 1993. "U.S. Geological Survey Estimation Procedure for Accumulation Size Distributions by Play." *Bulletin of the American Association of Petroleum Geologists,* Vol. 77, No. 3.

International Energy Agency (IEA), Organization for Economic Cooperation and Development (OECD). 1987. *Energy Conservation in IEA Countries.* OECD.

International Energy Agency (IEA), Organization for Economic Cooperation and Development (OECD). 1991. *Energy Efficiency and the Environment.* OECD.

Jochem, E., and T. Morovic. 1988. "Energy Use Patterns in Common Market Countries Since 1979." *Annual Review of Energy.*

Jones, D. W. September 1991. How Urbanization Affects Energy Use in Developing Countries." *Energy Policy.*

Long, D. January 1991. "Stability in Saudi Arabia." *Current History.*

McMullen, R. July-September 1993. "Ethnic Conflict in Russia: Implications for the United States." *Studies in Conflict and Terrorism.*

The Margin. November/December 1990.

Masters, C. D. 1993. "U.S. Geological Survey Petroleum Resource Assessment Procedures." *Bulletin of the American Association of Petroleum Geologists,* Vol. 77, No. 3.

Miller, R. G. 1992. "The Global Oil System: the Relationship Between Oil Generation, Loss, Half-life, and the World Crude Oil Resource." *Bulletin of the American Association of Petroleum Geologists,* Vol. 76, No. 4.

Oil & Gas Journal. January 10, 1994a. "Asia To Pace Growth in World Energy Demand."

Oil & Gas Journal. February 7, 1994b. "Geopolitical Trends Shape Future of World Petroleum Industry."

Oil & Gas Journal. March 7, 1994c. "EIA Cites Importance of Key World Shipping Routes."

Pavle, J. October 1989. "Gas Househeating Survey: 1988." *Gas Energy Review.*

Stanislaw, J., and D. Yergin. September/October 1993. "Oil: Reopening the Door." *Foreign Affairs.*

Time Magazine. January 28, 1991.

U.S. Central Intelligence Agency. September 1993. *Handbook of International Economic Statistics.*

U.S. Department of Commerce. 1992. *U.S. Statistical Abstract.*

U.S. Department of Energy (DOE), Office of Intelligence. June 1992a. *Identifying Vital Issues: New Intelligence Strategies for a New World. Volume 1: Vital Issues.* Washington, D.C.

U.S. Department of Energy (DOE), Office of Intelligence. September 1992b. *Identifying Vital Issues: New Intelligence Strategies for a New World. Volume 2: Critical Topics.* Washington, D.C.

U.S. Government Printing Office (GPO). 1993. *Economic Report of the President.*

U.S. International Trade Commission. June 1993. *Trade and Investment Patterns in the Crude Petroleum and Natural Gas Sectors of the Energy-Producing States of the Former Soviet Union.* Washington, D.C.

Wilhelm, K. April 17, 1994. "China's Energy Crisis: More Resources Needed to Power Economic Growth." *Seattle Post-Intelligencer.*

Yergin, D. 1991. *The Prize: The Epic Search for Oil, Money & Power.* Simon & Schuster.

About the Editor

Patrick L. Clawson is a Senior Fellow at the Institute for National Strategic Studies and the author of *Iran's Strategic Intentions and Capabilities* (McNair Paper 29); *Iran's Challenge to the West* (1993); and *Uprooting Leninism, Cultivating Liberty,* with Vladimir Tismaneanu (1992). Dr. Clawson is also the editor of *Strategic Assessment 1995* (NDU Press), the Institute's survey of U.S. security challenges in the post-Cold War period. A past editor of *Orbis,* Dr. Clawson was a senior economist at the World Bank and the International Monetary Fund.

*U.S. G.P.O.:1995-387-330:20012

Energy and National Security in the 21st Century

Composed in Avant Garde type
Titles in Caslon Open Face
Production editing and book design by Mary A. Sommerville
Cover design by Harry Finley